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ABSTRACT

Presented are guidelines for buying solar systems for the individual consumer. This is intended to help the consumer reduce many of the risks associated with the purchase of solar systems, particularly the risks of fraud and deception. Engineering terms associated with solar technology are presented and described to enable the consumer to discuss and evaluate systems on the market. The book does not attempt to describe all possible components of a solar system, but does treat main operating components. (Author/RE)

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Buying Solar

ED173179

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Solar energy is now in its infancy. Whether it grows to become a major factor in the Nation's energy supply will depend to a great extent on the Nation's buying public. The more informed consumers are about their choices in the marketplace, the greater the likelihood that solar manufacturers will compete over substance. When manufacturers compete in that fashion the base is laid for solid growth. The country needs to have this solid solar growth as well as growth in other alternate energy systems if our Nation is to become energy independent. For these reasons, and because of the consumer's own need for self-protection, it is important that the consumer receive as much accurate information as possible about solar systems. I am pleased that the Federal Energy Administration could work in partnership with the Office of Consumer Affairs to publish and distribute "Buying Solar."

Frank G. Zarb
Administrator
Federal Energy Administration

The dream of capturing energy directly from the sun is almost as old as man himself. Now that day has arrived, and perhaps no new energy technology has captured the imagination of the public as much as solar has. Beyond the excitement of the technology itself, there are other reasons why solar energy has become so popular. It is a nonpolluting, renewable form of energy that can lead to lower monthly bills; and it can provide the owner and the country a degree of independence from energy inflation and energy shortages.

All this enthusiasm, however, could vanish rapidly if solar systems do not live up to the public's expectations, if there are more disappointed buyers than satisfied owners of solar systems. This is the overall purpose of this publication--to give you, the reader, the information you need to protect yourself and to be an informed solar buyer.

Virginia Knauer

Virginia H. Knauer
Special Assistant to the President
for Consumer Affairs,
and Director, Office of Consumer Affairs,
Department of Health, Education, and Welfare

Buying Solar

June 1976

This book is dedicated to the many solar pioneers across the country who are making the hope of solar energy a reality today.

By: Joe Dawson, Director, Public Affairs, Office of Consumer Affairs, Office of Synfuels, Health, Education, and Welfare.

Solar Myths

Myth: It's a future technology.
Fact: It's here and working.
Myth: It only works down south.
Fact: It works in New England, too.
Myth: It's too expensive for the average homeowner.
Fact: Some solar systems are, some aren't.

Federal Energy Administration
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FOREWORD

Solar energy* for your home is here. It may help you individually and it certainly will help the country collectively.

Whether it will help you individually in terms of producing real savings depends upon a number of factors, including where you live, the type of home you have or intend to build, the quality of insulation in your home, your present energy costs, and the type of solar system you intend to purchase.

The purpose of this book is to give you information on these five factors so that you, as an informed customer, can make decisions related to solar space heating and cooling and domestic water heating that are in your best interests. By doing so, you will not only be doing a service to yourself, but to your fellow citizens.

Those who are able to and do use solar systems will help our nation save its precious fossil fuels. As you know from reading the headlines, our domestic supplies of oil and gas are very limited. There are just not enough domestic supplies available to meet all our future needs. And when Mother Nature says *that's all*, that's all. The only way we can prevent or delay her from uttering those fatalistic words is by starting to conserve energy now, and using, where possible, sources of unlimited energy such as solar.

We won't have to worry about the sun running out of energy for another several billion years or so.

*When solar energy is mentioned, the term is generally interpreted by the public to involve a solar collector which will provide energy to the home. Actually, solar energy has a broader meaning. It can involve photovoltaic energy, the direct conversion of the sun's energy into electricity; bioconversion, the utilization of agricultural or municipal wastes to provide fuel; ocean thermal, providing power by harnessing the temperature difference between the surface waters and the ocean depths; wind, harnessing wind energy to generate power; and solar thermal electric, concentrating the sun's rays to obtain high temperatures and thus generate electric power.

Besides being an almost infinite source of energy, solar has other advantages as well. When we use conventional sources to deliver energy to the home, we have serious problems to deal with, from the safe disposal of radioactive wastes to the pollution from fossil-fueled generating plants. With solar, we will still need these conventional sources of energy, but we won't need as much. That means that we can reduce our environmental and safety problems.

Further, owners of solar homes have extra protection against energy inflation and energy shortages. When utility costs go up, and they will go up, owners of solar homes may not have to face the possibility of considerably altering their lifestyles just to pay the utility bill. Cutoffs or curtailments of conventional fuels won't affect the owner of a solar home as m[illegible] as others.

With all these advantages, one might wonder why solar power is not more developed. There are many reasons, but a primary one is economics. Until recently, it was just not economical for a home owner to install a solar unit when there were cheap sources of conventional energy around. But those days are gone forever, and now solar is becoming increasingly competitive with electricity and oil. The present gas cost advantage over solar may change in the near future as a number of experts believe gas will triple in costs in the next few years. Too, gas is in such short supply that in many areas it is just not available for new customers. Some customers, in fact, are having their supplies curtailed.

Because solar energy has not been fully developed in the past, it poses some significant problems for the consumer in the present.

One main, obvious drawback is that the consumer has not had any experience in buying solar equipment. What questions does a potential buyer ask? How can he or she compare competing brands? How does a person get a unit repaired if it goes on the blink? What does a person do if his neighbor plants a tree and the tree throws a long shadow on the collector? Can the buyer trust the seller's claims for a particular solar unit? What happens to the unit when the owner goes on a vacation? How come there is no one under "solar" in the Yellow Pages? What happens if a vandal throws a rock at the collector?

The reader should know right away that this book won't give all the answers to all these questions or explain all systems, because in some cases, such as the important area of solar rights (your guaranteed right to access to the sun's rays without encroachment), there are no complete answers today. In other areas, such as measuring the efficiency of a collector, and evaluating different components, there are a few answers. But only an expert—a mechanical or an architectural engineer who has had background in solar—can give them to you. This is because what is a "smart" solar purchase for one consumer in one area may be a foolish buy for a consumer in another area.

This book does not explain to the consumer all the possible components in a system, nor all the systems available. Rather, it focuses on some of the main operating components such as the collector.

Some readers may be disappointed that observations are not given as to good or bad buys. The reader should remember that the Federal Government does not know all the systems available, and if several were selected as outstanding, it would be unfair to those whose products the government does not currently know about. The government should not be in a position of giving an unfair competitive advantage to any manufacturer. This policy, while certainly correct, unfortunately prevents our saluting many important solar pioneers and manufacturers.

SUN LANGUAGE

ABSORBER, or ABSORBER PLATE: A surface, usually blackened metal, in a solar collector which absorbs solar radiation.
ABSORPTANCE: The soaking up of heat in a solar collector. Measured as percent of total radiation available.
ACTIVE SOLAR SYSTEM: Any system that needs mechanical means such as motors, pumps, valves, etc., to operate.
AMBIENT TEMPERATURE: Another way of saying how cold or how hot it is outdoors.
BIOCONVERSION: Utilization of agricultural or municipal wastes to provide fuel.
BRITISH THERMAL UNIT (Btu): A unit of energy defined as the amount of energy required to heat one pound of water one degree Fahrenheit.
COLLECTOR, or SOLAR COLLECTOR: A device for receiving solar radiation and converting it to heat in a fluid.
COLLECTOR EFFICIENCY: The fraction of incoming radiation captured by the collector. If your system captures half of the incoming radiation, you have a system that is 50 percent efficient. Efficiency is the capability of a collector to capture Btu's under various climatic conditions. Efficiency varies according to outside temperatures, whether skies are clear or cloudy, whether it is windy or not, and, of course, the quality of the collector. There's no way a collector can be 100 percent efficient; that is, to capture all the Btu's that fall on the collector; 55 percent is good under desirable weather conditions.
COLLECTOR TILT: The angle measured from the horizontal at which a solar heat collector is tilted to face the sun for better performance.
CONCENTRATOR: Reflector or lens designed to focus a large amount of sunshine into a small area, thus increasing the temperature.
CONDUCTIVITY: The ease with which heat will flow through a material determined by the material's physical characteristics. Copper is an excellent conductor of heat; insulating materials are poor conductors.
CONVECTION: When two surfaces—one hot, the other cold—are separated by a thin layer of air, moving air currents (called convection currents) are established that carry heat from the hot to the cold surface.
EMITTANCE: A measure of the heat re-radiated back from the solar collector. Measured as fraction of the energy which would be radiated by a totally black surface at the same temperature.
FLUID: Any substance such as air, water, or antifreeze used to capture heat in the collector.
GALVANIC CORROSION: If you have this in your system, you have problems. This is caused when different metals are not isolated properly and a liquid comes in contact with both metals. The result is galvanic corrosion and repair bills.
HELIOSTAT: A mirror used to reflect the sun's rays into a solar collector or furnace.
HYBRID SOLAR SYSTEM: A system that uses both active and passive methods to operate (e.g., a solar system which uses pumps to heat and nocturnal cooling to cool).
INSOLATION: The rate of solar radiation received per unit area.
KILOWATT: One thousand watts of power; equal to about 1⅓ horsepower.
KILOWATT-HOUR (kWh): The amount of energy equivalent to 1 kilowatt of power being used for 1 hour = 3,413 Btu.
LANGLEY: A unit of measurement of insolation. (One langley equals one gram-calorie per square centimeter.) The langley was named for American astronomer Samuel P. Langley.
OCEAN THERMAL: Providing power by harnessing the temperature differences between the surface waters and the ocean depths.
PASSIVE SOLAR SYSTEM: A system that uses gravity, heat flows, evaporation or other acts of Mother Naure to operate without mechanical devices to collect and transfer energy (i.e., south facing windows).
PHOTOVOLTAIC: Direct conversion of the sun's energy into electricity.
PYRANOMETER: An instrument for measuring solar radiation.

RADIATION: Any object that is warmer than its surroundings radiates heat waves (similar to light waves, but invisible) and, thus, emits heat energy.
RERADIATION: After an object has received radiation or is otherwise heated, it often reradiates heat back. Generally speaking, matte black surfaces are good absorbers and emitters of thermal radiation while white and metallic surfaces are not.
SELECTIVE SURFACE: A special coating sometimes applied to the absorber plate in a solar collector. The selective surface absorbs most of the incoming solar energy and reradiates very little of it.
SOLAR CELL: A device, usually made of silicon, that converts sunlight directly into electrical energy.
SOLAR CONSTANT: The average amount of solar radiation reaching the earth's atmosphere per minute. This is just under 2 langleys, or 2 gram-calories per square centimeter. This is equivalent to 442.4 Btu/hr/ft^2, 1395 watts/m^2 or .1395 watts/cm^2.
SOLAR RIGHTS: An unresolved legal issue involving who owns the rights to the sun's rays.
SUN TRACKING: Following the sun with a solar collector to make the collector more effective.
SYSTEM EFFICIENCY: Btu's are lost from the time the sun's rays hit the collector to the moment they are used to heat the house or the water supply. The question is how many Btu's are used in comparison to the original number coming in. The answer is the efficiency of the whole system. **This is a very important consideration.**
THERMOSYPHON: The principle that makes water circulate automatically between a collector and a storage tank above it, gradually increasing its temperature.

SUN TERMS

K, or **THERMAL CONDUCTIVITY:** A measure of the ability of a material to permit the flow of heat. It expresses the quantity of heat per hour that will pass through a one-square-foot chunk of inch-thick material when a 1° F temperature difference is maintained between its two surfaces; K is measured in Btu/(hr)(ft^2)(°F)/foot or inch.
C: A measure of the heat flow through a given thickness of material. If you know a material's K, to find its C, divide by the thickness; e.g., 3" thick insulation with a K of 0.30 has a C of 0.10. The lower the K or C, the higher the insulating value.
U, or **OVERALL COEFFICIENT OF HEAT TRANSMISSION:** A measure of the ability of a complete building section (such as a wall) to permit the flow of heat. U is the combined thermal conduction value of all the materials in a building section, plus air spaces and air films. The lower the U, the higher the insulating value. U = Btu/(hr)(ft^2)(°F).
R, or **THERMAL RESISTANCE:** A measure of the ability of a substance to resist the flow of heat. R is simply the mathematical reciprocal of either C or U. Thus,

$$R = 1/C \text{ or } R = 1/U$$

Insulation products are typically characterized by their R values. Thus, a specification of R-11 means the insulation displays 11 resistance units. Clearly, the higher the R value, the better the insulating ability.
R is a simple common denominator for describing all types of insulation and all kinds of dwelling construction. For example, all insulation rated R-11 has the same insulation ability no matter what its material or thickness.

ACKNOWLEDGMENTS

This book will give you many guidelines for buying solar systems, it should eliminate a good many risks, and it should help protect you against possible fraud and deception. It should familiarize you with engineering terms used to evaluate or describe solar products. But eventually, if you are a smart consumer, you will obtain the advice of an expert—a person who can look at your individual circumstance and give you advice tailored to your particular home.

This book could not have been written without the invaluable assistance of my colleagues at the various energy agencies, a number of solar businessmen, and the solar books mentioned in the Bibliography. The reader should know that I am not a solar expert, rather a consumer writer. What I attempted to do was to solicit advice from the most knowledgeable experts I could find on the topic, and then translate this technical information into usable language. I want to thank in particular Ray Fields and Bill Rice from the Energy Research and Development Administration, and Norm Lutkefedder at the Federal Energy Administration. Also, I owe a deep debt of gratitude to John K. Freeman, Deputy Assitant Administrator for Energy Projects, Federal Energy Administration, for offering to publish this book. Unfortunately, I cannot name all the businessmen who helped me with this book because to do so would give them a competitive advantage. They know who they are, however, and they know how grateful I am. I am at liberty to name Sheldon Butt, president of the Solar Energy Industries Association. Sheldon spent many hours going over the text, and his suggestions and comments were most helpful. The solar industry is fortunate to have such an outstanding professional at the helm. If the solar industry reaches its full potential, as I am sure it will, a great deal of credit will go to Sheldon. The mention of all these experts is not intended to shift any responsibility for the final product. If there are any errors, I am the one at fault.

Finally, I want to thank Virginia H. Knauer, Special Assistant to the President for Consumer Affairs, for her support and encouragement. She understood the importance of this book, and she gave me the time to work on it. Virginia is a solar enthusiast and has undertaken a number of significant efforts to give this important form of energy a viable start. When the history of solar power is written, she will be included in one of the first chapters.

Joe Dawson
Director of Public Affairs
Office of Consumer Affairs

SOLAR SUBSYSTEMS—THE COLLECTOR

Every so often it seems, the American people learn about a totally new product in the marketplace. Several years ago, for instance, the hand electronic calculator was but a wink in a businessman's eye. Now, you can walk into almost any retail outlet and purchase one to keep your checking account in balance and to help figure out your income taxes.

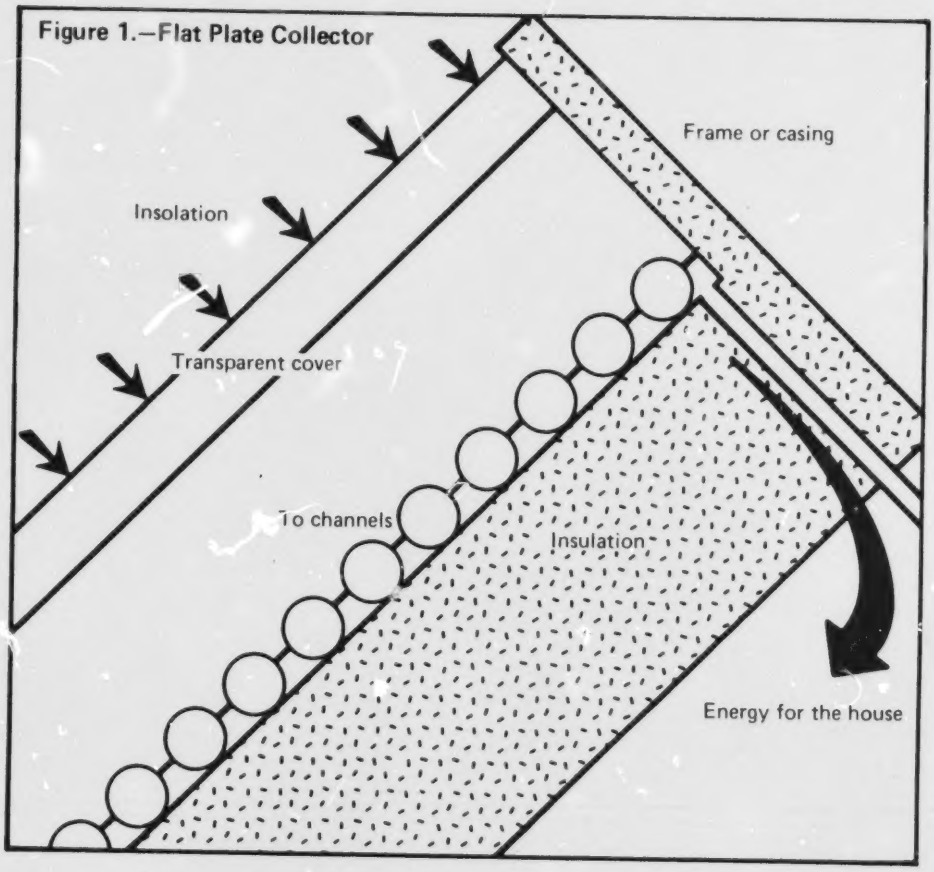
Similarly, it wasn't too long ago when stereo systems first came on the marketplace, and Americans heard a totally new language—woofers, tweeters, anti-static devices, distortion levels, etc. To choose properly, consumers had to learn what these terms meant, and then they had to learn how to compare competing products. Because so many Americans took the time and trouble to learn these essentials, stereo manufacturers by and large fought for the consumer's business by selling quality rather than imagery. Two important results occurred—superior products and satisfied customers.

Will solar evolve, as stereo did, into a widespread, beneficial industry? To a great extent, that answer depends upon you, the American consumer. The more people who take the time and effort to become good buyers, the greater the chance that solar power will reach its full potential—providing safe, economical energy to millions of American families.

To be a good buyer of solar systems does not mean you have to become a mechanical or an architectural engineer. It does mean that at the right time, you should call on one of these experts to give you specific advice for your specific home. But before you get to the point of bringing in the expert, there is a lot you can do to decide whether solar is for your home, and what type of unit is best for your needs.

Perhaps the best place to start is with knowledge of how solar works, and the various main subsystems that make up a solar system which are the collector, storage, the distribution network, and controls.

Figure 1.—Flat Plate Collector



The solar collector is the subsystem most people think about when solar energy is discussed. This is the component whose main function is to capture the sun's energy. There are many types of collectors available: high performance collectors such as the focusing collector which tracks the sun, a vacuum-sealed collector which has very low heat loss, and the more conventional flat plate collector. To understand the principle upon which a collector operates, let's take a look at the flat plate collector, which has been used successfully for residential and commercial purposes.

Beyond the casing and the insulation, the flat plate collector (see Figure 1) has three main elements—the transparent cover or covers, the collector plate known to engineers as the absorber, and the channels in the collector plate.

The transparent cover can be made out of glass or plastic. It is hard to generalize about the advantages and disadvantages of each material because various products differ in quality.

Glass holds its transparent characteristics well over the years. However, various quality characteristics such as transparency, strength, etc., vary from product to product. The same can be said of plastics. Some contain high transparency characteristics for long periods of time, while others do not. Some turn yellow, reducing the capability to transmit solar radiation. Some glass and plastic covers are almost vandal-proof, while others can be damaged very easily.

Some nonconductive material should separate the cover from the frame to decrease conduction losses.

In selecting collectors of different materials, the consumer should ask for test reports that show anticipated durability and transparency characteristics. You can then give these reports to your engineering consultant for evaluation.

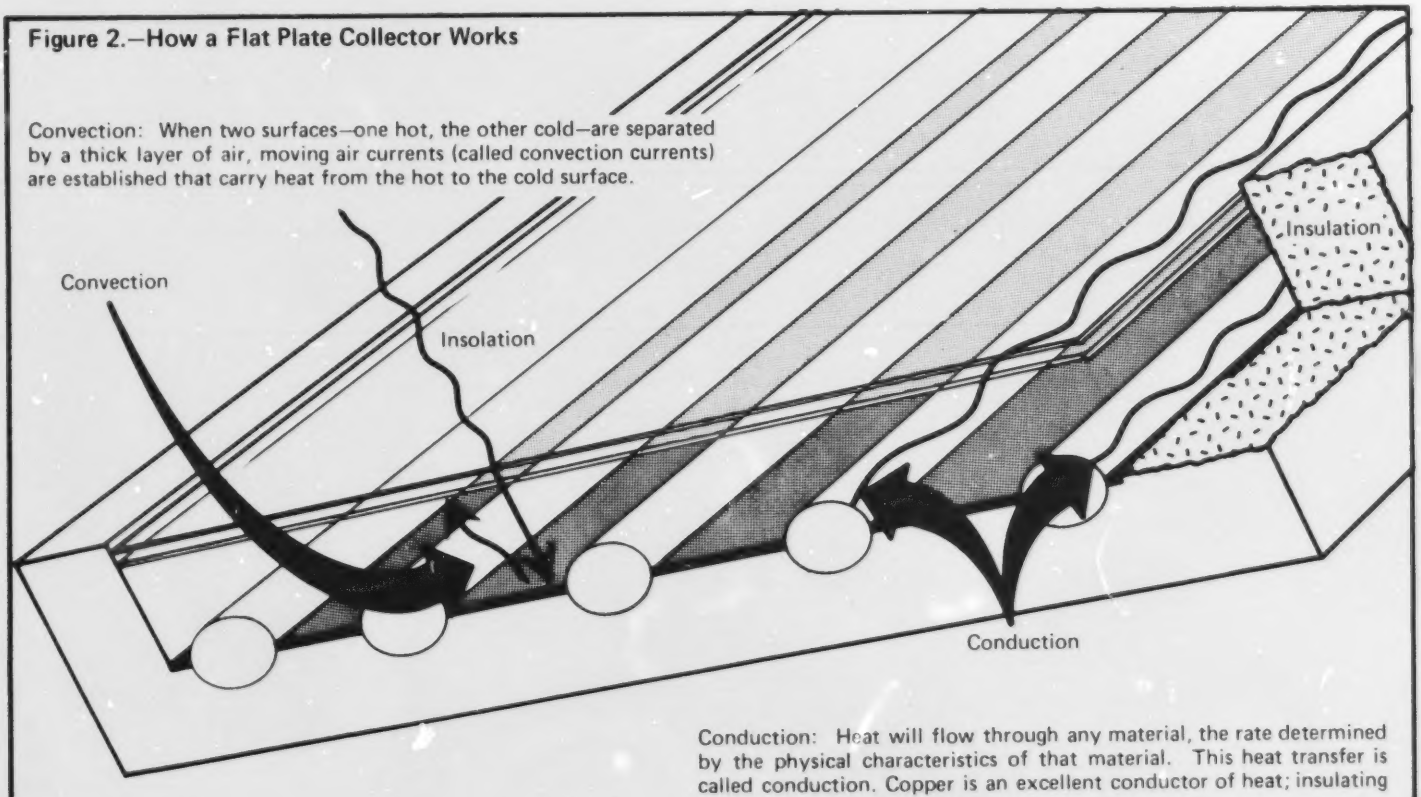
The transparent cover serves many purposes. It keeps outside air from carrying away the heat that has been trapped. It also keeps out the wind and the elements, protecting the inside components and reducing energy loss by convection. In warm areas, one cover is usually all that is necessary, but in colder climates, two transparent covers or insulated glass are generally considered necessary.

Here is how the typical flat plate collector works. Solar radiation passes through the transparent cover (a small portion is absorbed or reflected off the cover's surface) and hits the absorber plate. Most of the radiation is absorbed by the plate and picked up by the fluid (air, water, or other liquids) passing through the channels in or against the plate. Some of the radiation is reflected off the plate back to the cover—how much depends upon the absorbing and reflecting characteristics of the coating on the collector plate. The better the absorbing quality, the more radiation captured; the less reflected back to the cover. Special coatings have been developed which are highly absorptive with low reradiation. Don't be turned off by a collector plate because it is black or a dark color; dark colors absorb radiation much better than light colors. Conversely, you can't always tell by the color whether the coating has the desired selectivity characteristics.

Some manufacturers are developing what is known as selective surfaces for the collector plate. These are not painted, but rather specially coated metals that appear to be a technical improvement over flat black paint because reradiation losses are decreased. Selective surfaces cost more initially than flat black paint, and the extra cost must be weighed against the value of increased efficiency and the life expectancy of the coating. No matter what coating or metal is used, however, some portion of the incoming radiation will be radiated back, and of that portion, the transparent cover either will allow some to pass through or absorb the rest. The reason for two transparent covers in some collectors is to improve the insulation, just as storm windows on your house reduce the loss of heat through the window. More than two covers are not necessary. Still other por-

Figure 2.—How a Flat Plate Collector Works

Convection: When two surfaces—one hot, the other cold—are separated by a thick layer of air, moving air currents (called convection currents) are established that carry heat from the hot to the cold surface.



Conduction: Heat will flow through any material, the rate determined by the physical characteristics of that material. This heat transfer is called conduction. Copper is an excellent conductor of heat; insulating materials are poor conductors.

tions of the collected energy are lost from the collector plate through convection to the air space above and conduction by the metal in the plate, and through the insulation on the back and side (see Figure 2). How much is lost through conduction depends upon overall design of the collector. The net result of all these losses is that only a certain portion is absorbed by the passing fluid. The fewer the losses, the more efficient the collector.

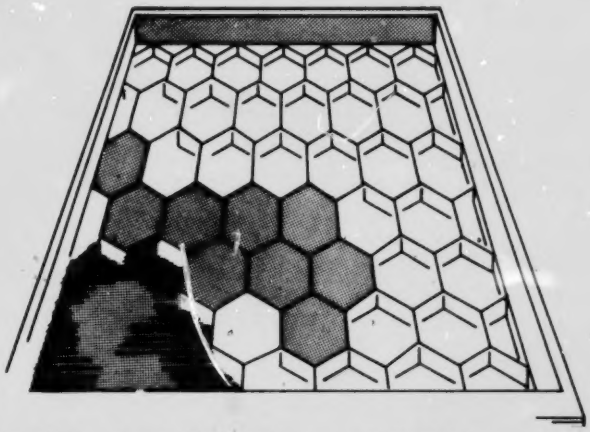
To reduce losses through convection, some collectors have honeycomb material located between the transparent cover and the collector plate (see Figure 3). This limits the formation of convection currents which are responsible for some of the loss.

The advantages of honeycomb in reducing convection losses may be offset by the greater expense and by increasing conduction losses if the honeycomb conducts heat from the collector plate to the transparent cover. In addition, the honeycomb should help the collector take stagnation temperatures—high temperatures which can occur when the collector is not working.

A properly designed honeycomb structure can add to the strength of a collector, increasing resistance to hail, and adding to the capability of the collector to replace the roof.

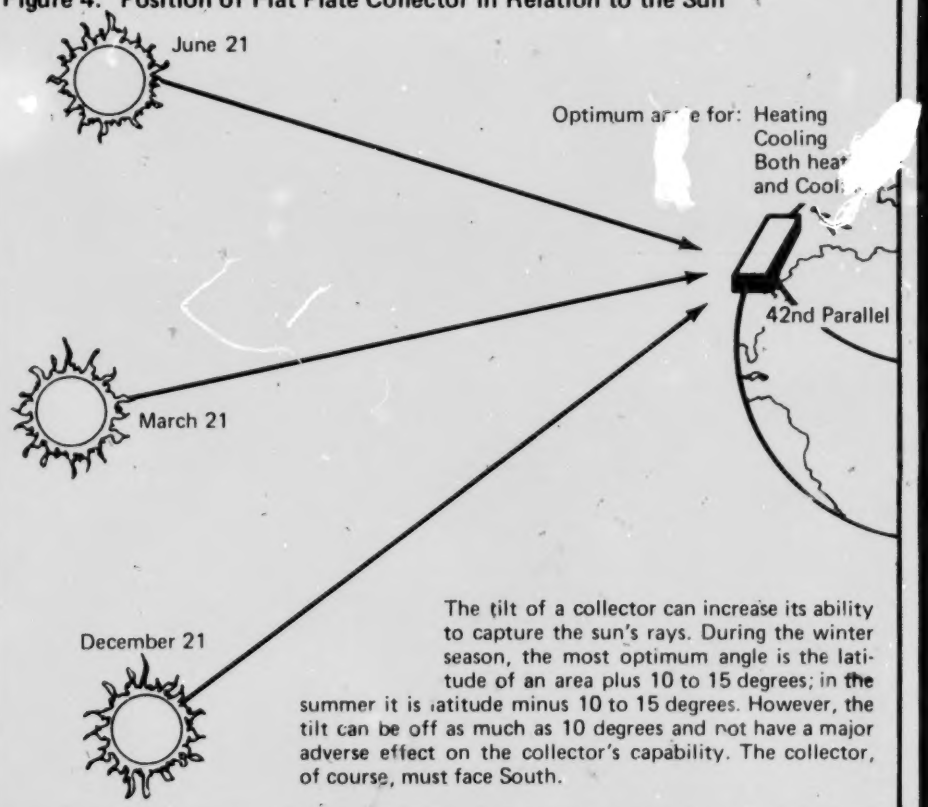
Depending upon local climatic conditions, an important design factor for a flat plate collector is its position in relation to the sun. If a solar system is designed for heating, the collector surface in most instances should be nearly perpendicular to the sun's rays in the middle of January, generally the coldest days of the year. This is usually an effective position for capturing the sun's rays (see Figure 4). This perpendicular position is the sum of your latitude plus 15 degrees.

Figure 3. Honeycomb Collector



A honeycomb collector has both advantages and disadvantages. It costs more, but properly built, it can reduce convection currents and add to the strength of the collector. An improperly built honeycomb collector can increase conduction currents.

Figure 4. Position of Flat Plate Collector in Relation to the Sun



The tilt of a collector can increase its ability to capture the sun's rays. During the winter season, the most optimum angle is the latitude of an area plus 10 to 15 degrees; in the summer it is latitude minus 10 to 15 degrees. However, the tilt can be off as much as 10 degrees and not have a major adverse effect on the collector's capability. The collector, of course, must face South.

If your solar system is for heating and cooling, the most optimum angle is near the latitude. If the system is for cooling only, you should mount the collector at an angle about 10 to 15 degrees less than the latitude.

Several precautionary notes should be considered on the optimum angle of the collector. If the collector is within 10 to 15 degrees of the optimum, it will not make much difference in the energy recovered by the collector. What all this means is that if you decide to put a flat plate collector on your roof, and your roof has a 45 degree tilt, and you live in Phoenix, there's no need to go to the added expense of building in the other 3 degrees on your collector. Similarly, if you hire an architect to design a solar house, don't get upset if he or she shades a few degrees off here or there to obtain some other desired end result. Further, some solar systems have a mirror or reflective surface next to the collector to augment the radiation reaching the absorber by reflecting extra sunlight into it. This is often done with cooling systems where higher temperatures are needed.

The ideal position of the collector for the greatest annual and seasonal energy recovery is facing due South. However, a variation of as much as 15 degrees in either direction will not significantly reduce the efficiency of the collector.

Concentrating collectors can only collect direct solar radiation, so they aren't much good on cloudy days. Flat plate collectors do not have this limitation and can pick up diffused radiation. The extra cost of the reflector must be weighed against the Btu's on sunny days only.

Beyond the main elements within the collector, it is important to keep in mind that soundness of construction is an important characteristic in obtaining an efficient collector. It must keep out wind, rain, and dust, so good sealants are necessary.

Another important feature of the collector is the insulation under the absorber plate to reduce downward heat losses. Some insulation does not hold up well over a long period of time under the very hot conditions present under the absorber. Fiberglass, 3 to 4 inches thick, holds up well. If you do not have efficient insulation, you will lose much of the heat collected, and have an inefficient collector. If the insulation does not hold up, you could be faced with periodic replacement, and high repair bills.

Determining the quality of a collector is a very complex process, and one which only a qualified engineer should undertake.

However, the consumer is likely to hear a lot about the efficiency of a collector, and by this is meant the ability of the collector to capture the sun's power. For instance, if it is said that a collector has a 50 percent efficiency, that means that under certain conditions, the collector captures 50 percent of the total energy hitting the surface of the collector.

There are many conditions that will affect the efficiency of a collector. Of primary importance is the amount of radiation you can expect in your area for the particular period in which you plan to use the solar system. For instance, if you plan to install a space heating system, you should know the efficiency of the collector during December, January, and February when you will need the system the most. How much radiation you can expect will depend upon the amount of sunshine and the atmosphere where you live. (Reports on atmosphere, cloudy days, temperatures, and radiation levels in various parts of the country are given on page 36.)

In some limited areas, there are so many cloudy days and many partially cloudy days that the amount of radiation reaching the collector will usually be found to be so small as to make it unlikely that it would be advantageous for you to install a solar system.

Further, the efficiency decreases as the temperature difference between the outdoors and the absorber plate increases. To put it in another way, the colder it gets on the outside, the more inefficient the collector will be. This is because the differences in temperatures cause an increase in energy loss through conduction and reradiation. Remember the definitions of convection and radiation:

Heat will always flow from a hot surface to a cold one when there is a medium such as air to transport the heat. When this occurs, it is called convection. In the collector, the air space serves as the medium, and the net result is convection currents. In colder weather, convection increases.

When an object is warmer than its surroundings, it radiates invisible heat waves to the colder areas. This is radiation. An object that has been warmed often reradiates heat back.

To show how efficiency varies among competing collectors in terms of temperature differences, the National Bureau of Standards has developed standards by which efficiency can be measured.

An increase in the flow of the fluid through the collector can help to reduce losses. For instance, if there is no movement at all, the fluid will become very hot and lose a great deal of heat. As the fluid starts moving, the temperature is reduced and heat losses are reduced.

Another factor affecting efficiency is the evenness of the flow of the fluid through the channels and the arrangement of the channel system; the more even the flow, the more efficient the system.

The temperature at which heat must be stored also has an effect on a system's efficiency. In some systems, heat must be stored at high temperatures (100 to 175 F) to keep the home warm so the collector must produce hotter water or air. The hotter the system operates, the lower the efficiency of the solar system. In other systems, heat is stored at lower

temperatures (85° to 125°F) and so the solar collector system operates at higher efficiency. Collector efficiency is only one of several considerations in system performance and quality, so the above comparison does not necessarily indicate that the lower temperature system should be the choice.

Now, why all the explanations about collector efficiency? First, to make the point that there are a number of complex engineering factors that have a bearing on how efficient a given collector is. Second, the efficiency of a collector is a major factor in determining a whole system's performance. Third, to give you—the consumer—some ideas for evaluating competing collectors.

Let's say that an engineering evaluation has been made of two competing collectors. Both are estimated to have a 20-year life span and require little maintenance and few repairs. Collector A costs $10 per square foot installed, while Collector B costs $6 per square foot. Both receive on a given day 200 Btu's per square foot per hour. Collector A has a 60 percent efficiency and will deliver 120 Btu's per hour per square foot. Collector B has a 50 percent efficiency and delivers 100 Btu's per hour per square foot. Which collector does the consumer choose?

If the two collectors are the same in all other aspects, he chooses Collector B because it delivers 20 Btu's per dollar while A delivers only 10 Btu's per dollar.

But it must be stressed that there are other considerations besides first cost and efficiency. The wise consumer will want to know whether the collector is covered by a warranty, what the warranty covers, and for how long. A warranty is either "full" or "limited."

If it is limited, it will only cover certain features, and not the whole product. The following are some major, extremely important considerations, some of which can only be determined by an expert:

- Durability of the product. How long is it expected to last? Is it weatherproof and does it shed water?

- Ease of repair. If something goes wrong, who will fix it, how long will it take to fix it, and are repair parts easily obtainable? And what will various repairs cost?

- Susceptibility to either freezing or overheating. There are a number of adequate solutions to both problems, but you should be sure your collector has built-in protection for both extremes. You should also have assurances that if the collector is used for hot water purposes, and if antifreeze fluid is used in the collector, it cannot mix with water for domestic use.

Systems using water or "corrosion inhibited" water solutions can be built so that the collector and exposed piping will drain when temperatures drop close to freezing or when the collector is not being used. Alternatively, a nonfreezing fluid can be used in place of water in the collector. Water-antifreeze (meaning ethylene glycol type antifreeze formulations such as those used in automotive cooling systems) are not recommended for use in consumer solar applications. Exposure of ethylene glycol antifreeze mixtures to high temperatures such as those encountered in most systems in the summertime accelerates the rate at which the ethylene glycol will degrade, forming acids which are corrosive to most metals, including copper and aluminum.

The "nonfreezing" fluid selected should be one which will not degrade at maximum temperatures expected, which can reach 400°F.

Electric warmers can be used to prevent freezing, and they are acceptable in southern areas of the country where freezing temperatures occur infrequently. In colder areas, however, the cost of operating an electric warmer might be prohibitive, and power failures can occur just when severe freezing weather might be encountered. Obviously, any such use of electric energy tends to defeat the purpose of a solar energy system.

Overheating could have a detrimental effect on a solar system, if there are no built-in protective devices in active systems. For a definition of active and passive systems, see page 9. You should ask what will happen to your collector if you go on a vacation for several weeks during the middle of the summer.

Corrosion and leakage problems must be considered. Metal corrosion can cause irreparable damage to a solar system and shorten a system's life span. More importantly, corrosion can cause serious health problems if the water is used directly by the user.

Suitable protection against corrosion depends upon the system and the metals used. Potable water is the water one uses for drinking and washing. Inhibited water means that chemicals have been added to the water to prevent corrosion. Nonfreezing, nonaqueous heat transfer fluids are various liquids used in a solar system to prevent freezing. Most of these fluids are noncorrosive to the three metals commonly used in solar systems, but are not drinkable.

These three metals are copper, steel, and aluminum. Copper is more expensive, but it can be used with most potable waters without inhibitors. Steel and aluminum are more economical, but inhibitors must be added to prevent corrosion in most systems. Copper will hold up over a long time without inhibitors, while steel and aluminum will fail quickly unless they have special coatings. In inhibited water, all three will last indefinitely as long as the inhibition is maintained. All three will hold up indefinitely in suitable nonaqueous, nonfreezing, heat transfer fluids.

Steel and aluminum must be electrically isolated from each other and from copper to avoid galvanic corrosion. Isolation is obtained by using insulated rubber or plastic connections to join dissimilar metals.

For leakage, another rule of thumb is that the greater the number of joints, the greater the possibility of leakage. You should know what happens if a leak occurs, how it will be fixed, who will fix it, and how much it will cost. Some liquid collectors with unique channel systems have reduced the need for soldered joints considerably without hurting the efficiency of the collector.

Solar collectors which supply hot air are generally free from problems associated with freezing, corrosion, and boiling. Air leakage in piping and joints between collector sections, although not potentially as damaging as in liquid collectors, can reduce efficiency. The purchaser of such equipment should therefore have assurance that the entire collector array will perform as well as individual sections or modules.

If possible, you should try to obtain the names of other buyers of the collector, and learn whether the buyer is satisfied with its performance, and whether the collector has lived up to the claims of the seller.

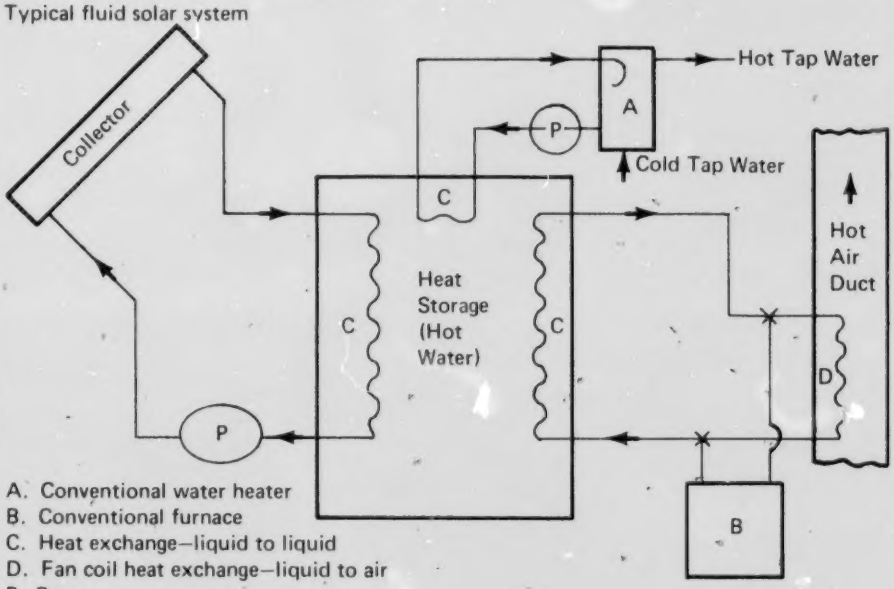
You should also ask whether the collector meets interim standards of the National Bureau of Standards. If the manufacturer claims such standards are met, you should get that in writing. These standards do provide a degree of assurance for the consumer, and if a seller claims such standards are met, he is legally accountable for that claim.

The seller's reputation is important, too. Whether a business is small or large, it will want and work for a good reputation. If you know the seller has a history of backing up and servicing the products he sells, then your chances of getting satisfactory service are improved.

A final point on collectors. To you, the most important points are total costs (including installation), the expected performance during the months you need the system the most, and how long the system is expected to last before it needs replacement.

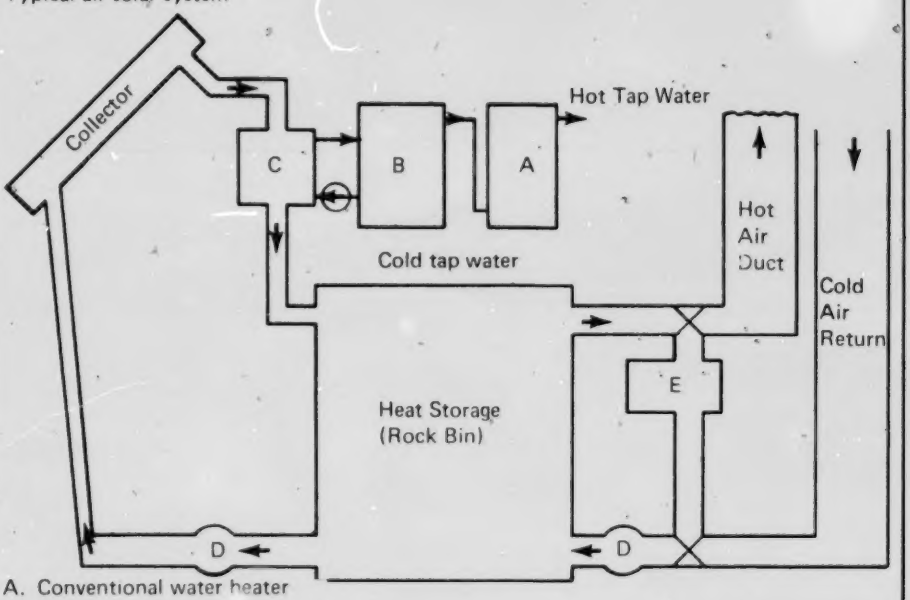
Solar Space Heating and Domestic Hot Water

Typical fluid solar system



A. Conventional water heater
B. Conventional furnace
C. Heat exchange—liquid to liquid
D. Fan coil heat exchange—liquid to air
P. Pump

Typical air solar system



A. Conventional water heater
B. Solar hot water storage
C. Air to liquid heat exchange
D. Blower
E. Conventional furnace

THE STORAGE SUBSYSTEM

Storage facility is the next important subsystem, after the collector, for most solar systems. Basically, the collector captures heat from the sun and transfers it to storage for later use.

There are three main methods for storage—water, rocks, and change-of-state storage (see Figure 5). Each has its advantages and disadvantages.

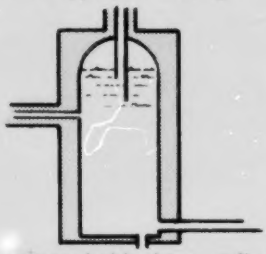
Water has the advantages of low cost and high heat capacity (the ability to contain heat effectively within a limited amount of space). Water storage tanks must be protected from freezing if located outside. Tanks must be protected from corrosion, either through use of a corrosion inhibitor in the water or by constructing them with corrosion-resistant material. Storage tanks must be heavily insulated to prevent the stored heat from being lost.

Materials currently used for water storage have both advantages and disadvantages. To insure that steel has a long lifetime, rust and corrosion inhibitors may be added. But, if so, much care must be taken to insure that the water in the system does not mix with the potable water. This is because inhibitors are toxic.

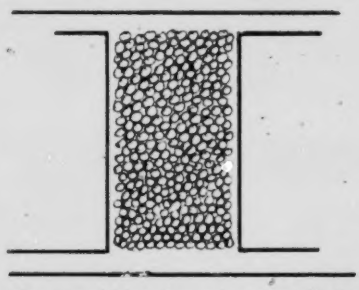
Plastic tanks do not have corrosion problems, but the types of plastic needed to store large quantities of water at high temperatures is rather expensive when compared with steel. Concrete is safe, durable, and economical, but if a leak develops, it is hard to repair. Great care must be taken to make certain that the tank is properly sealed when it is first built and installed. Some experts recommend bladders or diaphragms lining the tank to insure water tightness.

Weight is another important consideration. Two thousand gallons of water weigh about 9 tons. No matter where the storage system is located—in the basement or floor—adequate structural support must be provided for, and this is an area where you will need an engineering expert to give you specific advice for your home.

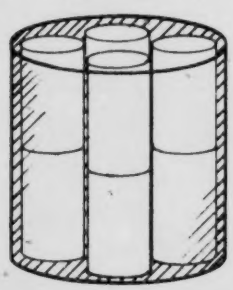
Figure 5.--Types of Storage



Water storage holds heat well and is economical, but the tank must be protected against corrosion and heat loss. It is the most practical method for storage of liquid systems.



Rocks or pebbles also are economical and retain heat well. No corrosion-proof tank is needed, but more space is required for the same amount of storage that water would provide. It is the most practical method of storage for air systems.



Change of state or salt storage is also economical and uses less space than water or air. But the salts can only go through so many heating and cooling cycles before they lose their capabilities to store heat. They have not been used on a commercial basis successfully yet. Some interesting experiments are being conducted which may prolong the number of cycles.

As discussed earlier, to prevent damage to the collector under freezing conditions, either a nonfreezing fluid must circulate through the collector or the collector must be built so that it drains when temperatures drop close to freezing. Although the amount of fluid needed in the collector itself is small and its cost is not an important factor, it is generally not practical to fill the large storage tank with the nonfreezing fluid. Therefore, a heat exchanger must be used to transfer heat from the fluid in the collector system to the water in storage if the collector fluid is expensive. A draining system eliminates this heat exchanger and its cost, as well as temperature losses occurring from the exchange. However, a draining system using water or inhibited water as the fluid depends in most instances upon the reliability of the draining mechanism to prevent costly freeze-up. Building reliability into such systems generally costs money.

Despite its limitations, water is at present the most practical method for storing heat for liquid-type solar collectors.

You should have assurances that the heat storage system is well insulated. Sprayed polyurethane foam, mineral wool insulation, fiberglass, and vermiculite are all excellent insulation materials for the outside of the tank.

For air-type solar collectors, rocks or pebbles are the most cost-effective way to store the collected heat. Rocks are easily obtainable, economical, and are not subject to problems stemming from corrosion, freezing, or leaking. Further, there is no need for an expensive container. However, rocks and pebbles do have two main disadvantages: they take up a lot of space and are much heavier than water. The space needed for storing heat with rocks is roughly three times the amount needed for water. This can be a major problem for some homes.

Another advantage of rocks is that they can be used to store heat at temperatures above 212 F, while water containers designed to carry temperatures over that

point need to be able to withstand pressure and can be costly unless a fluid is used that has a high boiling point. The ability of the rocks to reach higher temperatures is important because such heat will not go wasted if the collector delivers it.

For best results, the rocks or pebbles should be roughly spherical of uniform size, and up to 2 inches in diameter. These provide minimum resistance to the air passing through. Other solids can be used also, but are usually much more expensive.

The third method of storing solar energy, change of state storage, uses materials or substances that change composition from solid to liquid when heated. The changes permit the storage of more heat per pound than if the material did not change composition. When a material such as Glauber's salts is cooled, and goes from a liquid to solid state, it gives off this extra heat. This method, however, is still in the experimental stage.

The great advantage of change-of-state storage is that it can contain a great amount of heat in a limited space and at limited weight. Let's say that the objective of a storage system is to hold 200,000 Btu's at 100-160°F. Water systems would need 53 cubic feet at 3,300 pounds, rocks would need 175 cubic feet at 17,500 pounds, while Glauber's salts would require only 19 cubic feet at 1,740 pounds. In addition, such salts are obtainable at relatively reasonable prices.

Salt storage, however, has a number of major limitations. The salts can only go through so many cycles before their natural state is altered to the point whereby they lose their capacity to successfully store heat. There are some chemical additions which act to prolong the number of cycles considerably, and there are some interesting experiments which, if successful, may dynamically prolong the life span.

Second, though salts are economical, present costs for containerization and transportation are fairly expensive. Mass production could bring these costs down dramatically, but there are at present no marketable systems.

These are the two commercially available methods and one experimental method of storing heat. In choosing a system, you should, as with a collector, determine whether and what type of warranties are available. Depending upon the system, you will need to know answers to such specific questions as:

- (For water) What steps have been taken to provide protection against corrosion and freezing? How long is this protection expected to last? Is this life span estimate given in a guarantee?
- What types of maintenance are necessary, how much, and who will do it (owner or service personnel)? Is there easy access to the storage area?
- What is the heat storage capability of the system measured as Btu's stored within a specified temperature range? (Ask for the engineering calculations upon which this estimate was based. An engineering consultant should be able to easily determine the accuracy.) Remember, the storage should be large enough to absorb the full energy output of the collectors on an average sunny day.
- Are the insulation and structural methods sufficient?
- Is the warranty transferable?

THE SOLAR SYSTEM

Understanding the basic operations of a collector and a storage system is preparatory to knowing how a solar energy system works, and then determining whether you should invest in one, and, if so, what type.

There are four main end uses of a residential solar energy system: heating water for domestic use; heating a swimming pool; heating the home (space heating); and heating and cooling the home (space heating and cooling). Of course, there are various combinations of these end uses. A system could be used to heat the house during the winter, and the swimming pool in late spring or early fall when house heating is not needed. Or a unit could be designed to handle both heating of the home and supplying the hot water.

There are two basic types of systems. An active system uses mechanical means such as pumps, valves, and so on, for operating. A passive system uses natural forces such as gravity, convection, and nocturnal radiation, to accomplish the same objective. Both types of systems have their advantages and disadvantages.

Passive systems are more economical to operate. In some cases in certain climatic regions heating and cooling by solar is economically competitive with conventional forms of energy. However, these systems are limited by seasonal conditions and architectural restraints. They work well in hot, dry areas, but in cold temperatures or humid areas they are subject to such problems as freezing or excessive humidity. They may not be able to provide uninterrupted comfort levels. In most cases, the requirements of a passive system will dictate the overall design of the structure more so than with active systems. For instance, one type of passive cooling system requires a water pond on the roof with movable shutters which cool the home off by evaporation and nocturnal radiation. The shutters are closed during the daytime to prevent reheating. This system is most effective in areas of low humidity with clear night skies.

Active systems, properly designed, can work in almost any area. Initial costs for an active system are generally higher than those for a passive system, but costs may be more economical in terms of Btu's delivered per dollar invested. Active systems are not as architecturally restrictive as passive systems.

Some solar manufacturers utilize both passive and active techniques, combining some of the economic values of the passive system with some of the versatilities of the active method. These are called hybrid systems.

A conventional furnace (oil, gas, electricity) serves as a back-up energy source for most space heating and cooling, hot water, and some swimming pool solar systems. For cost effective reasons, most active solar systems are not designed to handle all the anticipated demand. If, for instance, a solar system were designed to handle 100 percent of the heating load during the middle of the winter, the collector and storage system would have to be large enough to provide energy for extended periods when the sun didn't shine. As these expanded units would only be used during limited periods, the extra cost normally isn't justified by the savings in fuel cost.

Beyond providing heat when the sun doesn't shine, conventional heat sources are often used directly in conjunction with solar heat. For instance, solar energy could be used to bring water up to a temperature of 100°F, and conventional energy used to boost the temperature another 40° for a dishwasher.

Some designers have used alternate energy systems such as wind power and wood stoves as a heat and power back-up, thus eliminating the need for utility service. However, the user would have to be prepared to accept inconvenience and occasional discomfort.

Within the system, there may be a vast array of components such as heat exchangers, relief valves and vents, controls, piping supports, and fans. These are very difficult for the average lay person to evaluate.

The best known solar method is hot water heating. These units have been in use in Florida since the early 1930's, and they have an overall record of acceptable performance when properly constructed and maintained.

Total costs depend upon the quality and size of the unit, the warranty offered, installation costs, and other variables. Because of fuel savings, they can return the original costs or pay for themselves within a reasonable period of time if replacing electricity or high-price fuel. The payback period depends upon the cost of conventional heating, the amount of water used by your household, the insolation rate, and the efficiency of the unit. Generally, these units save 50 to 80 percent of your water heating cost, again depending upon the unit and your location.

Beyond asking the questions posed previously about the collector, a consumer considering the purchase of a hot water unit should ascertain that the system meets local toxicity and potable water standards. These standards have been established to protect you against unsafe drinking water.

For hot water systems, the general rule of thumb for the size of the collector is about one square foot for every gallon of water required every day. Not counting dishwashing and washing machines, the average family uses about 15 gallons of hot water per person, and so with a family of four, a typical hot water installation would be about 60 square feet. This would take care of 50 percent to 80 percent of your total hot water needs depending upon climate with your conventional system supplying the remainder. A system could be designed, of course, to handle nearly all hot water needs.

Some solar heaters for swimming pools operate on the same basic principle as a hot water system, except that the storage area is not the hot water tank but the swimming pool. A number of experts sug-

gest that solar swimming pool systems be designed so that they could be used to heat domestic hot water. If you should decide to have a dual-purpose system, make sure that your collector is selected carefully.

Some solar swimming pool heaters use unglazed collectors. They can do this since the temperature to which it is desired to heat the pool is only a relatively few degrees above the outside air temperature. Unglazed collectors are very inefficient when operated at high temperatures, and may not be suitable for dual purposes.

One of the most effective and economical ways to heat a swimming pool is by using the pool itself as the solar collector and simply providing an easily removable durable transparent plastic membrane on the water surface. If maintained on the pool when not being used, water temperatures can be kept above 80 degrees for several months without fuel supplements.

As with hot water systems, it is important to have assurances that the swimming pool system water meets health and safety requirements.

If a separate collector is used, it should either be of the draining type or otherwise able to withstand freezing. Even though the night temperature of the air may be 40°F. or more, the collector could go below freezing due to nocturnal radiation. This process, nocturnal radiation, can also be used to cool the pool in summer months if the water becomes uncomfortably warm.

Structural stability, the capability of the solar unit to withstand high winds, and the compatibility of solar with conventional heating systems (if the two are supposed to work together) are other important considerations. You should obtain professional guidance on these matters.

Costs for swimming pool solar systems vary according to the temperature you want, how long you wish to operate the pool in the spring and fall months, and the local insolation rate.

Solar space heating systems offer much promise to the consumer in terms of dramatically reducing monthly enegy costs. Earlier we discussed advantages and disadvantages of various components within a system. These, of course, carry over to the system itself. Let's add up some of the pros and the cons of air and water systems.

AIR

Advantages

Moderate cost.

No freezing problems.

Minor leaks of little consequence.

As air is used directly to heat the house, no temperature losses due to heat exchangers (devices which transfer heat from one fluid to another), when the system is used for space heat.

No boiling or pressure problems.

Disadvantages

Can only be used to heat homes; cannot presently be economically adapted to cooling.

Large air ducts needed.

Larger storage space needed for rocks.

Heat exchangers needed if system is to be used to heat water.

WATER OR LIQUID

Advantages

Holds and transfers heat well.

Water can be used as storage.

Can be used to both heat and cool homes.

Compact storage and small conduits.

Disadvantages

Leaking, freezing, and corrosion can be problems.

Corrosion inhibitors needed with water when using steel or aluminum. There are liquids which are noncorrosive and nonelectrolytic; however, they are toxic and some of them are flammable.

A separate collector loop using a nonfreezing fluid and a heat exchanger or, alternatively, a draining water or inhibited water system, are required to prevent freezing. In warm regions, where freezing is infrequent, electric warmers can be used.

Some manufacturers are combining solar systems with heat pumps for the purpose of reducing auxiliary electricity costs. A heat pump is a device that has the capacity to extract heat from either cool air or cool liquid and increase the temperature to a useful level for heating. When used for cooling, the pump extracts heat from the house and then raises the temperature high enough to be dumped outside.

Your refrigerator is a type of heat pump. It simply extracts heat from inside the refrigerator and pumps it out, leaving the inside of the refrigerator cold. It does this through the circulation of a refrigerant, usually Freon.* Liquid Freon expands and evaporates in the coils inside the refrigerator. Upon evaporating, the Freon becomes much colder than the inside of the box; thus, it is actually heated by the inside of the refrigerator. A pump compresses this "warmed" gas, which causes it to heat up to temperatures higher than the room the refrigerator is in. The compressed gas then delivers its heat to the room through condenser coils where it "cools" and condenses back to a liquid and the cycle begins again.

So imagine that liquid Freon is moving through a tube which passes through water in storage. The Freon extracts the heat from the water by evaporation of this liquid. Then, as the Freon vapor is compressed, its temperature is raised to a temperature range of 100 to 150°F. This hot Freon vapor then flows through a heat exchanger which uses the heat in the Freon to heat your water or your air. The Freon is cooled and condensed to liquid in the exchanger and, after the liquid leaves the exchanger, it is allowed to expand to a low pressure. At the lower pressure, it evaporates at a low temperature, colder than storage, so it then can pick up more heat from the stored water to begin the cycle all over again.

Needless to say, the warmer the water in storage, the less work the heat pump needs to do to deliver useful heat. It works out, however, that the colder the stored water, the more efficiently the solar collector will function.

A heat pump can also be used to cool the house in summer. Here the cycle is reversed by operating valves and then the process is identical to the description of the refrigerator where the inside of the house is the same as the inside of the refrigerator.

The heat which the heat pump delivers to your house is the sum of the heat extracted from storage plus the electric energy delivered to the compressor of the heat pump. The total Btu's delivered by the heat pump to the house divided by the Btu's supplied by electricity is what engineers call the coefficient of performance. Thus, if 3 Btu's were delivered to the house for every Btu equivalent of electricity, the COP would be 3.

A problem with heat pumps, however, is that the colder the source used to evaporate the Freon, the lower the COP. This is where solar comes in. It can be used to heat the air or water thus reducing the work that the heat pump must do and thereby increasing the COP. As you can see, the higher the COP, the less electrical energy required for a given amount of useful heat delivered to the house.

One key advantage to the utilization of solar with heat pumps is that solar can be allowed to operate more effectively. As stated earlier, the efficiency of a solar system increases as the temperature of the fluid pumped through the collector decreases. Therefore, a solar collector is able to be operated at a lower temperature when used with a heat pump system and thus will collect more of the sun's energy for use than will a nonheat pump system. A properly designed heat pump solar energy system will have its collector working at peak efficiency and its heat pump supplying only the additional heat required of the house. In other words, the higher the average COP, the better.

Another way that a common air-to-air heat pump can be used in a solar heating system is by employing it as a furnace, to increase the temperature of air being supplied from the solar system to the distribution ducts. Outdoor air is used as the heat source for the heat pump, electricity providing the necessary temperature increase in the Freon cycle. Although this system does not have the higher collector efficiency of the design employing solar storage as the heat pump source, it does not suffer from mid-winter depletion of storage to temperatures consistently too low for direct solar heating without electricity supplement. Annual electricity usage in the two systems is not greatly different.

The heat pump replaces the furnace in your house at a considerably higher cost. On the other hand, if you live in an area where you cool your house in the summer anyway, a heat pump costs only a little more than a conventional Freon air conditioner. Systems using heat pumps for summer cooling may be able to use the storage system to store "coolness" during off peak hours and thus help alleviate the summer peaks that the electrical utilities experience on hot summer afternoons. If your utility system adopts off-peak pricing (costs are higher per kilowatt during periods of high use, lower during periods of low use), this solar-heat pump combination would work even further to your advantage. In the Washington, D.C. area, a house that requires a 4-ton air conditioning system will find that it actually operates only about 25 percent of the time. If water storage were to be used, a 1-ton unit could be used to handle the load by operating 100 percent of the time or, the 4-ton unit could be used only 6 hours a day at off-peak times.

*A registered trade-mark of DuPont.

Understanding how the total solar energy system works is important in beginning to uncerstand whether a unit can be used in your home. There are three basic questions a consumer must ask to determine that suitability:

1. Is it suitable for my house?
2. Is it a worthwhile investment?
3. Can I afford it?

This chapter and the next will discuss the first two questions. Only you can answer the third.

To begin with, solar energy is not suitable for everyone's house. You will have to know whether your house or lot can handle a large enough collector and storage system. Your collector will have to face a southern direction and receive enough unobstructed sunlight (see Figure 6). For your specific area, you will need to know how much usable radiation will fall during the time you intend to use your solar system. As will be explained later, this figure, the amount of usable radiation along with the system's efficiency and the size of the collector, will allow you to determine how many Btu's you will receive.

Here are a few approximate space needs for various systems:

For hot water systems, the general rule of thumb is 1 square foot of collector area for every gallon of water required per day. In other words, for a family that uses 80 gallons a day, an 80-square foot collector will be needed for the solar heater to furnish about three-fourths of the hot water in a sunny climate.

For swimming pools, the rough estimate is 1 square foot of collector for every 2 square feet in the pool. If a pool is 600 square feet, you will need about a 300-square foot collector. A transparent pool cover-heater is the same area as the pool.

There are many variables to take into consideration to determine the approximate space needs for a solar heating system, but, as a rough calculation, estimate 1 square foot of collector for every 2½ to 4 square feet of house. So if you have a well-built, 1,500-square foot house in a cold, sunny climate, about 500 square feet of collector can supply two-thirds to three-fourths of the annual heat requirements. As the efficiencies of collectors increase in the future, the size of the collector necessary will decrease.

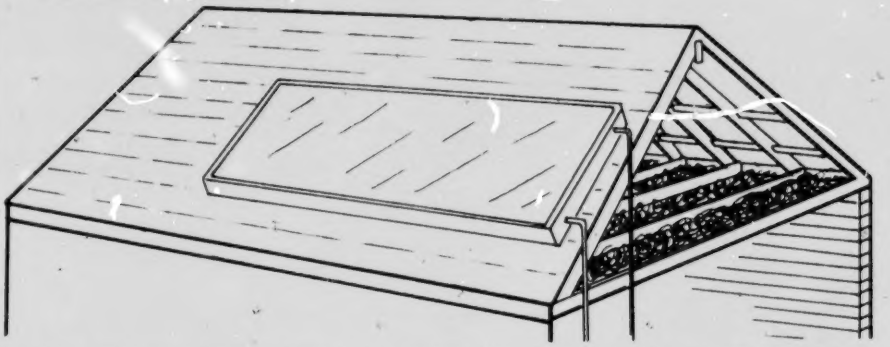
Approximate space needed for storage is as follows: For rock systems, about ½ cubic foot of rock storage for every square foot of collector; for water, about 1 to 2 gallons (0.13 to 0.25 cubic feet) of storage for every square foot of collector; for salt (when commercialized), about 1 cubic foot of storage for every 9 square feet of collector. There are a number of factors which will determine the actual size of your system.

For example, in winter, the people in Maine do not receive as much sun as those who live in Virginia. Consequently, those who live in Maine will need a larger collector to accomplish the same end results. (Yet the economics of solar heating

Figure 6. Solar Installations

Two important points about solar installation:

1. *Insulate* before you *insolate*! Caulking, storm windows, sufficient attic and wall insulation—all can save you vast amounts of heat at a cost lower than what it would take to provide you the same amounts of heat through a solar system. However, once you have the installation in your house, your solar system can deliver Btu that won't get lost in the cold night air.



2. Your solar collector shouldn't have a major obstruction in front of it. Trees that lose their leaves in winter are acceptable for a space heating system, but when the leaves are in place, they will adversely affect a hot water or space cooling system.

are much better in Maine than in Miami.) Similarly, you may decide for any number of reasons to limit the use of your collector, having it only provide 50 percent of a hot water load, for instance, rather than 80 percent.

In considering whether a solar space heating system will be suitable for your home, an important question concerns insulation. To exaggerate to make a point, if you have too many holes in the wall, you better patch them up with sufficient insulation before you consider a solar system.

Be sure the money to buy solar equipment isn't better spent on reducing heat losses. Some utility companies will do a free cost analysis on where the greatest losses are and how much it will cost to reduce them.

With improved insulation in the house and with some attention to heat recovery, the collector and storage space needs could be reduced dramatically. *It cannot be stressed often enough that the key is conserving conventional fuel and reducing utility bills is to insulate then insolate.*

The reason for this is simply sound economics. The reason you will be buying solar energy is to save money on your heating bill. If you are losing heat because of poor insulation, it is more economical to save heat through better insulation than by adding heat through a solar system. Once you have a soundly insulated house, then you will be able to determine whether the purchase of a solar energy system is worth the investment. You will have made every Btu count, and you will not be using a solar energy system to heat up the outside.

At the risk of indulging in some engineering terminology, let's look at some of the ways an engineer calculates heat losses and why insulation is so important in factoring solar. Heat losses are expressed through what is known as a "U" value. The U value stands for the amount of Btu's lost per hour per square foot for every degree of temperature difference between the inside and the outside of the house.

For instance, let us say that a single pane of window glass has a U value of 1.5. This would mean that the glass would lose 1.5 Btu per hour per square foot for every degree difference between the inside and outside of the house.

If we wanted to find out how many Btu's we were losing a day through the windows, we would simply take the square footage of the windows and multiply the temperature difference times 1.5 times 24 (for the hours in the day). As an example, let's say that the inside of the house was 65° and outside it was 0°, and there were 100 square feet of windows in the house. We would be losing 1.5 × 100 × 65 × 24 = 234,000 Btu's through the windows every day! Now let's take a look at how U values can come down considerably with proper insulation.

Material	*U Value*	*Number of Btu's lost per day per F° with a 50° temperature difference*
Single Pane of Glass	1.5	1,800
Double Pane	.55	660
Double Pane With Insulated Shutter	.10	120
Insulated Wall	.07	84
Super Insulated Wall (etc.)	.04	48

You can see how these losses can really cost by looking at the comparison below of two similar homes, one insulated, the other not insulated. The total savings per day in the insulated house is 453,345 Btu! In other words, the uninsulated house would cost dearly to heat in the wintertime.

Simple 25′ x 25′ uninsulated house, frame construction, crawl space below, attic above, seven windows, two doors, 65° F inside

	Uninsulated					*Insulated*		
	Area F²	*"U"*	*°T*	*Hrs/D*	*Loss Btu/D*	*"U"*	*Loss Btu/D*	*Saving Btu/D*
Walls	900	.25	25°	24	135,000	.10	54,000	81,000
Ceiling	625	.65	25°	24	243,750	.075	28,125	215,625
Floor	625	.38	25°	24	142,500	.06	22,500	120,000
Windows	84	1.13	25°	24	56,952	.53	26,712	30,240
Doors	40	.64	25°	24	15,360	.37	8,880	6,480

Both the Department of Commerce and the Department of Housing and Urban Development have developed excellent booklets on insulation. Information on these will also be found in the appendix.

You won't be able to completely eliminate heat losses, but you can reduce them substantially. And once you have, you and your engineering consultant can better determine whether solar power is a sound investment for you. Methods of determining the feasibility of installing solar in individual homes can be found in the Appendix.

If you plan to build a new home, you are in an excellent position to utilize a solar energy system and insulation. It is important to bring on the architect as soon as possible—before the site is even selected. Be sure that the architect has had experience in designing solar energy systems. Solor designing is a specialty, one requiring knowledge of how the mechanical and architectural systems work together.

A good solar engineer can put it all together for you. He can make the collector part of the roof, thus saving you expenditures. He can make sure the site is suitable for solar and reduce the possibility of future arguments about legal solar rights (see below). He can check out all the building codes, tax provisions, and other applicable local laws. Through proper design, he can make maximum use of energy conservation techniques, such as the proper placement of windows and natural convection.

If you are planning to retrofit your house, it is still wise to bring an engineering consultant on board (see Appendix). But before doing that, take a good look at where you live to determine whether you could possibly become involved in a future dispute over solar rights.

Very briefly, solar rights is an unresolved legal issue concerning access to the sun's rays. If your neighbor plants a tree which blocks the rays of the sun from reaching the collector, can you do anything about the tree? Or instead of a tree, supposing it is a high rise building. What legal rights do you have?

Right now, there are few answers to all these questions. You could have a lawyer draw up a covenant with your neighbor which would protect you against blockage. Other than that, you will have to use plain common sense. If you are in an area that is safely zoned, single-family residential, and you have enough space for a system and are so situated that your neighbors won't encroach on your sun space, then you are in a good position to plan. But if you are close to a developing commercial area, then you are taking risks. One state has passed a law preventing the shading of a neighbor's solar collector, and others may follow.

Whether you plan on building a new home or retrofitting an old one, you should check with your local building and zoning authorities to insure that your solar system doesn't run counter to present legal provisions. And don't forget the tax assessor. You may find to your surprise that a solar system will cost you more in taxes. So even though you are doing your country a favor by saving energy, you still may be taxed for it. If this should be the case in your area, let your local politician know about it. It will make good campaign material. Some states already give a property tax exemption.*

Your banker and your insurance agent are two other important personalities.

You will need to talk to your insurance agent about protection against vandalism (if this could be a problem in your area) and possible malfunctioning of the system—leaking, corrosion, hail, etc.

You shouldn't experience too much difficulty getting proper coverage from your insurance agent, but before you sign on the dotted line, ask whether your present homeowner's policy covers vandalism, and whether a collector would be included in the coverage. You may not need extra protection.

As discussed earlier, you may need a full-size furnace for those periods when no solar heat is in storage and very cold weather occurs. The backup is ordinarily an inexpensive furnace identical with that used in conventional systems.

*States which have passed property tax incentives include Indiana, Arizona, Colorado, Illinois, Maryland, Montana, New Hampshire, North Dakota, Oregon, and South Dakota. Arizona and New Mexico have passed legislation providing income tax incentives to buyers of solar systems. Texas has exempted the sale, lease, or rental of solar equipment from taxation.

SOLAR AS AN INVESTMENT

Is solar a good investment for you? The question is simple, the answer is complex. To know why, one might compare buying solar with buying a house as opposed to renting one.

When you buy a house, you slowly but surely gain ownership. When the day finally comes that you pay your last mortgage payment, it's all yours. No more payments. If you have to sell before you make the last installment, you certainly won't lose much from your investment and, in fact, you probably will receive more for your home than you paid for it while saving on tax deductions. But to realize a return or a profit on your investment, you will have to undertake regular maintenance and repair activities. If you rent, you don't have to worry about maintenance and repair, but when it comes time to move, all those rental dollars are lost forever.

Buying solar is somewhat the same, but with a few important differences. When you buy a solar system, you are concerned about initial and lifetime costs. There are today some new home builders who claim that costs for their residences with hybrid or passive solar systems are close to prices for comparable homes with conventional heating and cooling systems. If these systems function properly, then the consumer can expect a very short payback period—that is, the time needed when the savings from using solar energy will pay for the extra costs of the system.

If you are going to buy an active system, however, your initial costs will be much larger than the price for a conventional system, and your payback period will be much longer. You will in a sense be paying for several years' supply of energy all at once. As with passive systems, you will have to be concerned about durability. Maintenance and repair costs will add to the time needed to pay back on the system. But when the solar system is paid for, you will have free energy coming into your home. If you relied on a conventional system, it would be like renting—no hope of ever regaining the dollars spent for the operation of a conventional system.

However, as with renting a home, renting or leasing a solar system may provide you with some advantages. If, for instance, you were offered the rental of a solar system for $25 a month, repairs and maintenance included, with an estimate that it would save you $40 a month in utility costs, then you could come out ahead by $15 a month or $180 a year if the projections were correct. You would never own the system, but you would obtain some savings with no repair or maintenance problems to worry about.

There are times when a solar system is not a smart purchase, when conventional systems are a better buy. You may find that initial costs are prohibitive, or that the time period to pay back your investment is too long for your needs. Or that some of the unknowns about solar, such as solar rights and property appreciation or depreciation, are too risky.

Several examples of solar appraisals by an engineering firm are given in the appendix. As you will see, this firm recommended solar systems in some instances, while vetoing it in other cases. The fee ($100) was very reasonable and for it the buyer was assured of quality evaluations —specific advice on how to save on energy costs. Risks were reduced to a minimum, and the buyer may have saved himself thousands of dollars by taking the engineer's advice.

But you should know how the engineers do it, so that at least you will know how to evaluate sales literature. What the engineers do (and what many businesses do) is to undertake a life-cycle cost analysis. Simply put, this means all the money spent on a system versus all the savings. On the debit side for a solar system, you will have initial costs, anticipated annual maintenance costs, interest and principal payments on a loan (which may be pivotal), extra insurance, possible tax increases, and possible depreciation. On the plus side, you will have annual savings (as opposed to operating costs for a conventional system), possible extra appreciation for the house due to the solar system, possible tax breaks from the Federal or State government, tax deductions for your interest payments, and energy inflation (may also be pivotal). Some of these factors, such as taxes, are sometimes difficult to analyze, and you or your engineering consultant will have to determine from local, State, and Federal authorities what the outlook is when it comes time to buy. Further, because some solar systems do not have an historical track record, annual maintenance costs may be hard to calculate. But again, a good engineering consultant will give you some estimate as to how durable a system may be.

What all these calculations come down to is the amount of time you will need to recover your investment. If the payback period is, say 10 years, and you have a sound, durable product, you can be fairly assured that the system will hold up for that period before any major extensive repairs or replacements are needed. If the payback period is longer, say 20 years, then your risks will be appreciably higher.

Any life-cycle analysis of a solar system begins with an evaluation of the Btu requirements for the specific end use of your solar system.

For hot water systems, you need to know how much hot water you and your family use per month. You can compute that roughly from your present bills (from 15 to 20 percent of the total bill in cases where hot water and heat come from the same system), or you can base usage on the national average.

For swimming pools you determine the amount of Btu's needed by the size of the pool, the temperature desired, and the period of extended use.

Determining the heating and cooling needs of a house is a complex process and will be explained in greater detail below, but basically you will need the

design heat (or cooling) loss for the house, the Degree Days Per Month, or the Cooling Days Per Month. Information on Degree Days can be found on page 21.

Once you have an understanding of your approximate Btu needs per month, you will then need to calculate approximately how many Btu's of solar heat will be delivered to your house. This calculation is determined by the average amount of insolation falling during a particular period in your area per square foot, the size of your collector, the efficiency of your system, and the portion of the collected solar heat that can be used. (Heat has to be thrown away during some periods.)

On page 48, you will see a payback period estimation prepared by a major manufacturer. This estimate is based on the competing costs of conventional fuel, the amount of solar insolation, and the yearly efficiency of the system. There is also an adjusted payback period based on the premise that the solar home will appreciate considerably. In looking at the price and payback period, remember that these are the estimates of just one manufacturer. Other costs and savings estimates may differ considerably.

There are several points of clarification. The payback period did not, on the one hand, take into consideration possible maintenance costs, loan interest, and possible tax disadvantages. On the other hand, neither did the calculations take into account energy inflation, which probably will be considerable, and possible tax advantages.

Furthermore, the gas and oil estimates are conservative. The figures do not reflect inefficiencies in gas and oil heating systems. In other words, though a gallon of oil is equal to 140,000 Btu's, about 55,000 Btu's are lost when the oil is burned in a heater. The estimates did not take into consideration these losses.

Another assumption is that the house is well insulated, with no major preventable heat losses.

In addition, remember that such overall calculations apply to a general area; they may not apply to a specific location. In other words, you may live in an area where, because of high costs for conventional fuel and because of the high insolation rate, solar systems appear to be particularly attractive. Yet the particular site of your home—in the shadow of a mountain, for instance—may negate these cost and insolation advantages.

With that all said and done, the chart at the end of this chapter can be helpful to you in determining the basic advantages of solar in your general area. By finding out the costs of *available* competing fuels (electric—kilowatt hours, oil—gallons, or gas—cubic feet), and the insolation rate (low: 250-350 langleys per day, average 300; medium: 350-450, average 400; and high: 450-550, average 500), you can quickly determine the competitiveness of solar in your area. The insolation levels for various sections of the country can be found on page 36.

There is also included in the Appendix a cost-benefit analysis of various systems prepared by the Solar Energy Industries Association. This analysis takes into consideration possible appreciation and depreciation and evaluates purchases by area. In reviewing this particular study, remember that electric, gas, and oil rates change rapidly, and the costs quoted for conventional fuel are probably outdated.

The basic ingredients for a life-cycle analysis are the total *installed* costs of a solar system versus the anticipated benefits, which basically are the number of Btu's you can properly anticipate to meet your needs. The first part of this basic equation, total installed costs, should be easy to obtain. The amount of Btu's you can anticipate for various solar systems for your specific home, however, is not that easy to determine.

For all solar systems—hot water, swimming pool, space heating and cooling—you will need the following weather data for a thorough calculation of anticipated Btu return:

- Monthly solar insolation data.
- Monthly average ambient temperature.
- Monthly average wind velocities.
- Heating degree-day data and the base for calculating degree days.
- Cooling degree data and the base used in calculating degree days.
- Unusual weather conditions, overcast, rain, hail, dust conditions.

(A quick note on *Heating Degree Days*. This is a computation used to determine the heating requirements of a house. It is determined by subtracting the average ambient temperature over a 24-hour period from a base of 65 degrees. In other words, if the average temperature for a given day is 45 degrees, then the *Degree Days* for that day would be 20. For *Degree Days* in a month or in a season, one simply adds all the *Degree Days*. The greater the number of *Degree Days*, the greater your heating needs. How *Degree Days* are used will be explained on page 25. *Degree Days* for your area can be found on page 21.)

Beyond the weather data, a proper evaluation of anticipated benefits requires other information based on the objective of the solar system. This data is also needed to determine the design specifications for your system.

For hot water systems, the following information is needed:

- Type and capacity of water heater now used.
- Number of hot water outlets.
- List of appliances using hot water.
- Number of persons in the household.
- Fuel consumption of water heater.
- Desired water temperature.
- Time of day when most hot water is used.
- Temperature of cold water supply.

Swimming pool systems require the following data:

- Size of pool—width, length, average depth.
- Present pool heater.
- Fuel used in present system.
- Is the pool covered when not used?

- Length of swimming season without heat.
- Desired length of use.
- Temperature and source of water supply.
- The presence or lack of a wind barrier.

For space heating and cooling, the following information is needed:

- The orientation of the house.
- Floor area of the home, and the number of stories.
- Type of construction used, type and extent of insulation.
- The mean U value or heat loss of the home, including infiltration and ventilation.
- Previous bills and rates.
- Desired temperature levels.

Beyond the weather and specific use data, topographical information, latitude, altitude, and description of the specific site—hills, trees, valleys, etc.—will also be needed.

If you buy a solar system without taking all these factors into account, then, frankly, you are gambling.

Actually determining the amount of Btu's delivered is a rather complicated process, and readers may want to skip the following explanation. But you may want to look at how one manufacturer calculates Btu usage.

This Solar System Will Handle Up To 90 Percent of Your Heating Needs

Beware of simplistic claims. They generally have a catch. The above claim may only apply to homes that have extravagant insulation. Below is a more modest and more accurate claim.

On a Good Sunny Day, This Solar System Will Handle Between 40 and 60 Percent of Your Heating Needs.

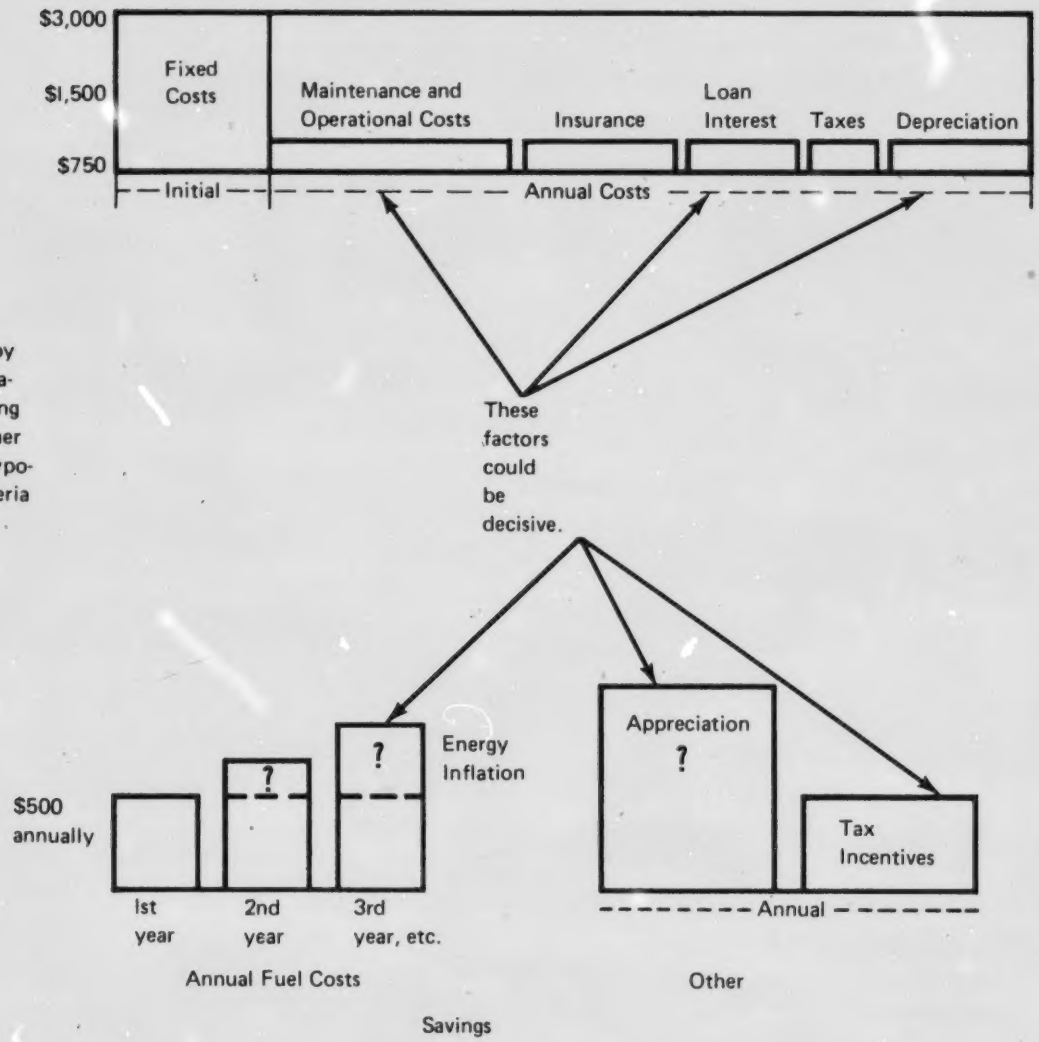
Knowing the differences among warranties can make a big difference in your pocketbook.

FULL WARRANTY

This product is guaranteed against all defects in construction and against corrosion for a period of 5 years. Manufacturer will pay for all labor and parts costs to correct problems.

LIMITED WARRANTY

This product is guaranteed to be one of the finest solar systems ever manufactured. Manufacturer will pay for costs of parts to correct any problem.



Life cycle costing is a method whereby the total costs of a product can be measured against the annual savings, showing the buyer approximately when his or her investment is paid for. The above is a hypothetical example showing some key criteria in such an evaluation.

The following procedure is used to determine precise fuel savings for specific collector areas:

Nomenclature

Design Load - The design heating load of the residence or commercial building of interest.

Design Temperature - The winter outdoor design temperature for the building location (i.e. in Denver the Design Temperature = 0° F)

Internal Heat Gain - The internal heat gain of the building due to lights, occupancy and machinery. For residences this is generally assumed to be 0.

A_c - The collector area in square feet

UA - The heat loss per degree day of the building. This number is obtained from the Design Load. Multiply the Design Load by 24 hours and divide the product by the design T(70 - Design Temperature).

qu - The useful heat gain from the collector on a per square foot basis. The dimensions of this number are BTU/ft² - month.

dg dys/month - The 30 year average degree days per month where dg days = $(65 - \frac{T_{maximum} + T_{minimum}}{2})$ $T_{maximum}$ = daily maximum temperature

$T_{minimum}$ = daily minimum temperature.

These numbers are tabulated by the National Weather Service.

Heat Load - The total average heat load per month which equals UA × dg dys.

Procedure

The Design Load is taken directly from the Heat Loss Calculation. The Design Temperature is taken from ASHRAE or Manual J. The Internal Heat Gain is obtained from the Heat Loss and Gain Summary for a commercial building. The Internal Heat Gain in such a summary is usually given in BTU/hr, and must be converted into BTU/Month. To do this, the Internal Heat Gain in BTU/hr is multiplied by the number of hours per month the heat addition to the building is occuring. For example, if the internal heat gain from lights and people is given as 10,000 BTU/hr for an office building, then the total for one month is:

$$\text{Int. Ht. Gn} = 10{,}000 \frac{\text{BTU}}{\text{hr}} \times \frac{8 \text{ hours}}{\text{day}} \times \frac{21 \text{ working days}}{\text{month}} = 1{,}680{,}000 \text{ BTU/month}$$

The UA of a building is the heat loss per dg dy of the building and is obtained directly from the design heat load as explained under Nomenclature above. This calculation assumes the building is to be kept at approximately 70° F, and if this is not the case, the performance chart cannot be used directly.

qu and dg dys/month have been tabulated for several locations in Table II.

The tabulated values of qu and the collector output in BTU/Sq.Ft. per month are entered in Column 1 of the percent annual fuel savings worksheet (Worksheet II).

Column 2 is the total heat gain from the collector and is obtained by multiplying qu by A_c, the collector area.

Dg dys/month are entered in Column 3.

Column 5 is the portion of the total heat loss which has to be met by the heating system. These numbers are obtained by subtracting the internal heat gain from the total heat loss calculated in Column 4. If the difference is negative, enter 0.

Column 6 is the portion of the heat load met by the back up system. It is obtained by subtracting the numbers in Column 2 (the total heat gain from the collector) from the corresponding numbers in Column 5 (the Heat load). If this number is negative, then the solar system has satisfied the entire load and 0 is entered.

Column 7 is the percentage of the load carried by solar for each month and is obtained by subtracting Column 6 from Column 5, dividing the product by Column 6 and multiplying by 100 percent. The annual percentage of the load carried by solar is obtained similarly to the monthly percentages. The total from Column 5, dividing the product by the total of Column 6, and multiplying by 100 percent.

Worksheet II - Sample Problems

Sample Worksheets A through E provide details for Worksheet II use based on a house in Boston, Massachusetts with a design heat load of 68,790 BTU/hour. The design ambient temperature is 10° F. These worksheets show performance for collector areas of 500 square feet, 1,000 square feet, 1,200 square feet and 1,500 square feet. It can be clearly seen that as collector area increases, the number of months in which the Solaron system provides 100 percent of the monthly heating requirement increases from three months at 500 square feet to five months at 1,200 square feet. It also becomes apparent when totaling the percent of solar heating from 500 square feet of collector at 39.8 percent and from 1,000 square feet of collector at 67.1 percent, that more than doubling the collector area does not necessarily double the percent of total heating provided by the solar system. This is, of course, a function of climatological data. From such a presentation, the proper collector area from a cost effectiveness viewpoint can be selected. The worksheets provide the following summary for the sample structure:

Collector Area Square Feet	% of Total Heating Provided by Solar
500	39.8
800	56.8
1,000	67.1
1,200	76.1
1,500	85.8

Source: Colorado State University

Normal Total Heating Degree Days (Base 65°)

STATE AND STATION	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	ANNUAL
ALA. BIRMINGHAM	0	0	6	93	363	555	592	462	363	108	9	0	2551
HUNTSVILLE	0	0	12	127	426	663	694	557	434	138	19	0	3070
MOBILE	0	0	0	22	213	357	415	300	211	42	0	0	1560
MONTGOMERY	0	0	0	68	330	527	543	417	316	90	0	0	2291
ALASKA ANCHORAGE	245	291	516	930	1284	1572	1631	1316	1293	879	592	315	10864
ANNETTE	242	208	327	567	738	899	949	837	843	648	490	321	7069
BARROW	803	840	1035	1500	1971	2362	2517	2332	2468	1944	1445	957	20174
BARTER IS.	735	775	987	1482	1944	2337	2536	2369	2477	1923	1373	924	19862
BETHEL	319	394	612	1042	1434	1866	1903	1590	1655	1173	806	402	13196
COLD BAY	474	425	525	772	918	1122	1153	1036	1122	951	791	591	9880
CORDOVA	366	391	522	781	1017	1221	1299	1086	1113	864	660	444	9764
FAIRBANKS	171	332	642	1203	1833	2254	2359	1901	1739	1068	555	222	14279
JUNEAU	301	338	483	725	921	1135	1237	1070	1073	810	601	381	9075
KING SALMON	313	322	513	908	1290	1606	1600	1333	1411	966	673	408	11343
KOTZEBUE	381	446	723	1249	1728	2127	2192	1932	2080	1554	1057	636	16105
MCGRATH	208	338	633	1184	1791	2232	2294	1817	1758	1122	648	258	14283
NOME	481	496	693	1094	1455	1820	1879	1666	1770	1314	930	573	14171
SAINT PAUL	605	539	612	862	963	1197	1228	1168	1265	1098	936	726	11199
SHEMYA	577	475	501	784	876	1042	1045	958	1011	885	837	696	9687
YAKUTAT	338	347	474	716	936	1144	1169	1019	1042	840	632	435	9092
ARIZ. FLAGSTAFF	46	68	201	558	867	1073	1169	991	911	651	437	180	7152
PHOENIX	0	0	0	22	234	415	474	328	217	75	0	0	1765
PRESCOTT	0	0	27	245	579	797	865	711	605	360	158	15	4362
TUCSON	0	0	0	25	231	406	471	344	242	75	6	0	1800
WINSLOW	0	0	6	245	711	1038	1054	770	601	291	96	0	4782
YUMA	0	0	0	0	148	319	363	228	130	29	0	0	1217
ARK. FORT SMITH	0	0	12	127	450	704	781	596	456	144	22	0	3292
LITTLE ROCK	0	0	9	127	465	716	756	577	434	126	9	0	3219
TEXARKANA	0	0	0	78	345	561	626	468	350	105	0	0	2533
CALIF. BAKERSFIELD	0	0	0	37	282	502	546	364	267	105	19	0	2122
BISHOP	0	0	42	248	576	797	874	666	539	306	143	36	4227
BLUE CANYON	34	50	120	347	579	766	865	781	791	582	397	195	5507
BURBANK	0	0	6	43	177	301	366	277	239	138	81	18	1646
EUREKA	270	257	258	329	414	499	546	470	505	438	372	285	4643
FRESNO	0	0	0	78	339	558	586	406	319	150	56	0	2492
LONG BEACH	0	0	12	40	156	288	375	297	267	168	90	18	1711
LOS ANGELES	28	22	42	78	180	291	372	302	288	219	158	81	2061
MT. SHASTA	25	34	123	406	696	902	983	784	738	525	347	159	5722
OAKLAND	53	50	45	127	309	481	527	400	353	255	180	90	2870
POINT ARGUELLO	202	186	162	205	291	400	474	392	403	339	298	243	3595
RED BLUFF	0	0	0	53	318	555	605	428	341	168	47	0	2515
SACRAMENTO	0	0	12	81	363	577	614	442	360	216	102	6	2773
SANDBERG	0	0	30	202	480	691	778	661	620	426	264	57	4209
SAN DIEGO	6	0	15	37	123	251	313	249	202	123	84	36	1439
SAN FRANCISCO	81	78	60	143	306	462	508	395	363	279	214	126	3015
SANTA CATALINA	16	0	9	50	165	279	353	308	326	249	192	105	2052
SANTA MARIA	99	93	96	146	270	391	459	370	363	282	233	165	2967
COLO. ALAMOSA	65	99	279	639	1065	1420	1476	1162	1020	696	440	168	8529
COLORADO SPRINGS	9	25	132	456	825	1032	1128	938	893	582	319	84	6423
DENVER	6	9	117	428	819	1035	1132	938	887	558	288	66	6283
GRAND JUNCTION	0	0	30	313	786	1113	1209	907	729	387	146	21	5641
PUEBLO	0	0	54	326	750	986	1085	871	772	429	174	15	5462
CONN. BRIDGEPORT	0	0	66	307	615	986	1079	966	853	510	208	27	5617
HARDFORT	0	6	99	372	711	1119	1209	1067	899	495	177	24	6172
NEW HAVEN	0	12	87	347	648	1011	1097	991	871	543	245	45	5897
DEL. WILMINGTON	0	0	51	270	588	927	980	874	735	387	112	6	4930
FLA. APALACHICOLA	0	0	0	16	153	319	347	260	180	33	0	0	1308
DAYTONA BEACH	0	0	0	0	75	211	248	190	140	15	0	0	879
FORT MYERS	0	0	0	0	24	109	146	101	62	0	0	0	442
JACKSONVILLE	0	0	0	12	144	310	332	246	174	21	0	0	1239
KEY WEST	0	0	0	0	0	28	40	31	9	0	0	0	108
LAKELAND	0	0	0	0	57	164	195	146	99	0	0	0	661
MIAMI BEACH	0	0	0	0	0	40	56	36	9	0	0	0	141
ORLANDO	0	0	0	0	72	198	220	165	105	6	0	0	766
PENSACOLA	0	0	0	19	195	353	400	277	183	36	0	0	1463
TALLAHASSEE	0	0	0	28	198	360	375	286	202	36	0	0	1485
TAMPA	0	0	0	0	60	171	202	148	102	0	0	0	683
WEST PALM BEACH	0	0	0	0	6	65	87	64	31	0	0	0	253

Normal Total Heating Degree Days (Base 65°)

STATE AND STATION	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	ANNUAL
GA. ATHENS	0	0	12	115	405	632	642	529	431	141	22	0	2929
ATLANTA	0	0	18	127	414	626	639	529	437	168	25	0	2983
AUGUSTA	0	0	0	78	333	552	549	445	350	90	0	0	2397
COLUMBUS	0	0	0	87	333	543	552	434	338	96	0	0	2383
MACON	0	0	0	71	297	502	505	403	295	63	0	0	2136
ROME	0	0	24	161	474	701	710	577	468	177	34	0	3326
SAVANNAH	0	0	0	47	246	437	437	353	254	45	0	0	1819
THOMASVILLE	0	0	0	25	198	366	394	305	208	33	0	0	1529
IDAHO BOISE	0	0	132	415	792	1017	1113	854	722	438	245	81	5809
IDAHO FALLS 46W	16	34	270	623	1056	1370	1538	1249	1085	651	391	192	8475
IDAHO FALLS 42NW	16	40	282	648	1107	1432	1600	1291	1107	657	388	192	8760
LEWISTON	0	0	123	403	756	933	1063	815	694	426	239	90	5542
POCATELLO	0	0	172	493	900	1166	1324	1058	905	555	319	141	7033
ILL. CAIRO	0	0	36	164	513	791	856	680	539	195	47	0	3821
CHICAGO	0	0	81	326	753	1113	1209	1044	890	480	211	48	6155
MOLINE	0	9	99	335	774	1181	1314	1100	918	450	189	39	6408
PEORIA	0	6	87	326	759	1113	1238	1025	849	426	183	33	6025
ROCKFORD	6	9	114	400	837	1221	1333	1137	961	516	236	60	6830
SPRINGFIELD	0	0	72	291	696	1023	1135	935	769	354	136	18	5429
IND. EVANSVILLE	0	0	66	220	606	896	955	767	620	237	68	0	4435
FORT WAYNE	0	9	105	378	783	1135	1178	1028	890	471	189	39	6205
INDIANAPOLIS	0	0	90	316	723	1051	1113	949	809	432	177	39	5699
SOUTH BEND	0	6	111	372	777	1125	1221	1070	933	525	239	60	6439
IOWA Burlington	0	0	93	322	768	1135	1259	1042	859	426	177	33	6114
DES MOINES	0	9	99	363	837	1231	1398	1163	967	489	211	39	6808
DUBUQUE	12	31	156	450	906	1287	1420	1204	1026	546	260	78	7376
SIOUX CITY	0	9	108	369	867	1240	1435	1198	989	483	214	39	6951
WATERLOO	12	19	138	428	909	1296	1460	1221	1023	531	229	54	7320
KANS. CONCORDIA	0	0	57	276	705	1023	1163	935	781	372	149	18	5479
DODGE CITY	0	0	33	251	666	939	1051	840	719	354	124	9	4986
GOODLAND	0	6	81	381	810	1073	1166	955	884	507	236	42	6141
TOPEKA	0	0	57	270	672	980	1122	893	722	330	124	12	5182
WICHITA	0	0	33	229	618	905	1023	804	645	270	87	6	4620
KY. COVINGTON	0	0	75	291	669	983	1035	893	756	390	149	24	5265
LEXINGTON	0	0	54	239	609	902	946	818	685	325	105	0	4683
LOUISVILLE	0	0	54	248	609	890	930	818	682	315	105	9	4660
LA. ALEXANDRIA	0	0	0	56	273	431	471	381	260	69	0	0	1921
BATON ROUGE	0	0	0	31	216	369	409	294	208	33	0	0	1560
BURRWOOD	0	0	0	0	96	214	298	218	171	27	0	0	1024
LAKE CHARLES	0	0	0	19	210	341	381	274	195	39	0	0	1459
NEW ORLEANS	0	0	0	19	192	322	363	258	192	39	0	0	1385
SHREVEPORT	0	0	0	47	297	477	552	426	304	81	0	0	2184
MAINE CARIBOU	78	115	336	682	1044	1535	1690	1470	1308	858	468	183	9767
PORTLAND	12	53	195	508	807	1215	1339	1182	1042	675	372	111	7511
MD. BALTIMORE	0	0	48	264	585	905	936	820	679	327	90	0	4654
FREDERICK	0	0	66	307	624	955	995	876	741	384	127	12	5087
MASS. BLUE HILL OBSY	0	22	108	381	690	1085	1178	1053	936	579	267	69	6368
BOSTON	0	9	60	316	603	983	1088	972	846	513	208	36	5634
NANTUCKET	12	22	93	332	573	896	992	941	896	621	384	129	5891
PITTSFIELD	25	59	219	524	831	1231	1339	1196	1063	660	326	105	7578
WORCESTER	6	34	147	450	774	1172	1271	1123	998	612	304	78	6969
MICH. ALPENA	68	105	273	580	912	1268	1404	1299	1218	777	446	156	8506
DETROIT (CITY)	0	0	87	360	738	1088	1181	1058	936	522	220	42	6232
ESCANABA	59	87	243	539	924	1293	1445	1296	1203	777	456	159	8481
FLINT	16	40	159	465	843	1212	1330	1198	1066	639	319	90	7377
GRAND RAPIDS	9	28	135	434	804	1147	1259	1134	1011	579	279	75	6894
LANSING	6	22	138	431	813	1163	1262	1142	1011	579	273	69	6909
MARQUETTE	59	81	240	527	936	1268	1411	1268	1187	771	468	177	8393
MUSKEGON	12	28	120	400	762	1088	1209	1100	995	594	310	78	6696
SAULT STE. MARIE	96	105	279	580	951	1367	1525	1380	1277	810	477	201	9048
MINN. DULUTH	71	109	330	632	1131	1581	1745	1518	1355	840	490	198	10000
INT FALLS	71	112	363	701	1236	1724	1919	1621	1414	828	443	174	10606
MINNEAPOLIS	22	31	189	505	1014	1454	1631	1380	1166	621	288	81	8382
ROCHESTER	25	34	186	474	1005	1438	1593	1366	1150	630	301	93	8295
SAINT CLOUD	28	47	225	549	1065	1500	1702	1445	1221	666	326	105	8879

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STATE AND STATION	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	ANNUAL
MISS. JACKSON	0	0	0	65	315	502	546	414	310	87	0	0	2239
MERIDIAN	0	0	0	81	339	518	543	417	310	81	0	0	2289
VICKSBURG	0	0	0	53	279	462	512	384	282	69	0	0	2041
MO. COLUMBIA	0	0	54	251	651	967	1076	874	716	324	121	12	5046
KANSAS	0	0	39	220	612	905	1032	818	682	294	109	0	4711
ST. JOSEPH	0	6	60	285	708	1039	1172	949	769	348	133	15	5484
ST. LOUIS	0	0	60	251	627	936	1026	848	704	312	121	15	4900
SPRINGFIELD	0	0	45	223	600	877	973	781	660	291	105	6	4561
MONT. BILLINGS	6	15	186	487	897	1135	1296	1100	970	570	285	102	7049
GLASGOW	31	47	270	608	1104	1466	1711	1439	1187	648	335	150	8996
GREAT FALLS	28	53	258	543	921	1169	1349	1154	1063	642	384	186	7750
HAVRE	28	53	306	595	1065	1367	1584	1364	1181	657	338	162	8700
HELENA	31	59	294	601	1002	1265	1438	1170	1042	651	381	195	8129
KALISPELL	50	99	321	654	1020	1240	1401	1134	1029	639	397	207	8191
MILES CITY	6	6	174	502	972	1296	1504	1252	1057	579	276	99	7723
MISSOULA	34	74	303	651	1035	1287	1420	1120	970	621	391	219	8125
NEBR. GRAND ISLAND	0	6	108	381	834	1172	1314	1089	908	462	211	45	6530
LINCOLN	0	6	75	301	726	1066	1237	1016	834	402	171	30	5864
NORFOLK	9	0	111	397	873	1234	1414	1179	983	498	233	48	6979
NORTH PLATTE	0	6	123	440	885	1166	1271	1039	930	519	248	57	6684
OMAHA	0	12	105	357	828	1175	1355	1126	939	465	208	42	6612
SCOTTSBLUFF	0	0	138	459	876	1128	1231	1008	921	552	285	75	6673
VALENTINE	9	12	165	493	942	1237	1395	1176	1045	579	288	84	7425
NEV. ELKO	9	34	225	561	924	1197	1314	1036	911	621	409	192	7433
ELY	28	43	234	592	939	1184	1308	1075	977	672	456	225	7733
LAS VEGAS	0	0	0	78	387	617	688	487	335	111	6	0	2709
RENO	43	87	204	490	801	1026	1073	823	729	510	357	189	6332
WINNEMUCCA	0	34	210	536	876	1091	1172	916	837	573	363	153	6761
N. H. CONCORD	6	50	177	505	822	1240	1358	1184	1032	636	298	75	7383
MT. WASH. OBSY.	493	536	720	1057	1341	1742	1820	1663	1652	1260	930	603	13817
N. J. ATLANTIC CITY	0	0	39	251	549	880	936	848	741	420	133	15	4812
NEWARK	0	0	30	248	573	921	983	876	729	381	118	0	4859
TRENTON	0	0	57	264	576	924	989	885	753	399	121	12	4980
N. MEX. ALBUQUERQUE	0	0	12	229	642	868	930	703	595	288	81	0	4348
CLAYTON	0	6	66	310	699	899	986	812	747	429	183	21	5158
RATON	9	28	126	431	825	1048	1116	904	834	543	301	63	6228
ROSWELL	0	0	18	202	573	806	840	641	481	201	31	0	3793
SILVER CITY	0	0	6	183	525	729	791	605	518	261	87	0	3705
N. Y. ALBANY	0	19	138	440	777	1194	1311	1156	992	564	239	45	6875
BINGHAMTON (AP)	22	65	201	471	810	1184	1277	1154	1045	645	313	99	7286
BINGHAMTON (PO)	0	28	141	406	732	1107	1190	1081	949	543	229	45	6451
BUFFALO	19	37	141	440	777	1156	1256	1145	1039	645	329	78	7062
CENTRAL PARK	0	0	30	233	540	902	986	885	760	408	118	9	4871
J. F. KENNEDY INTL	0	0	36	248	564	933	1029	935	815	480	167	12	5219
LAGUARDIA	0	0	27	223	528	887	973	879	750	414	124	6	4811
ROCHESTER	9	31	126	415	747	1125	1234	1123	1014	597	279	48	6748
SCHENECTADY	0	22	123	422	756	1159	1283	1131	970	543	211	30	6650
SYRACUSE	6	28	132	415	744	1153	1271	1140	1004	570	248	45	6756
N.C. ASHEVILLE	0	0	48	245	555	775	784	683	592	273	87	0	4042
CAPE HATTERAS	0	0	0	78	273	521	580	518	440	177	25	0	2612
CHARLOTTE	0	0	6	124	438	691	691	582	481	156	22	0	3191
GREENSBORO	0	0	33	192	513	778	784	672	552	234	47	0	3805
RALEIGH	0	0	21	164	450	716	725	616	487	180	34	0	3393
WILMINGTON	0	0	0	74	291	521	546	462	357	96	0	0	2847
WINSTON SALEM	0	0	21	171	483	747	753	652	524	207	37	0	3595
N. DAK. BISMARCK	34	28	222	577	1083	1463	1708	1442	1203	645	329	117	8851
DEVILS LAKE	40	53	273	642	1191	1634	1872	1579	1345	753	381	138	9901
FARGO	28	37	219	574	1107	1569	1789	1520	1262	690	332	99	9226
WILLISTON	31	43	261	601	1122	1513	1758	1473	1262	681	357	141	9243
OHIO AKRON	0	9	96	381	726	1070	1138	1016	871	489	202	39	6037
CINCINNATI	0	0	54	248	612	921	970	837	701	336	118	9	4806
CLEVELAND	9	25	105	384	738	1088	1159	1047	918	552	260	66	6351
COLUMBUS	0	6	84	347	714	1039	1088	949	809	426	171	27	5660
DAYTON	0	6	78	310	696	1045	1097	955	809	429	167	30	5622
MANSFIELD	9	22	114	397	768	1110	1169	1042	924	543	245	60	6403
SANDUSKY	0	6	66	313	684	1032	1107	991	868	495	198	36	5796
TOLEDO	0	16	117	406	792	1138	1200	1056	924	543	242	60	6494
YOUNGSTOWN	6	19	120	412	771	1104	1169	1047	921	540	248	60	6417

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STATE AND STATION	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	ANNUAL
OKLA. OKLAHOMA CITY	0	0	15	164	498	766	868	664	527	189	34	0	3725
TULSA	0	0	18	158	522	787	893	683	539	213	47	0	3860
OREG. ASTORIA	146	130	210	375	561	679	753	622	636	480	363	231	5186
BURNS	12	37	210	515	867	1113	1246	988	856	570	366	177	6957
EUGENE	34	34	129	366	585	719	803	627	589	426	279	135	4726
MEACHAM	84	124	288	580	918	1091	1209	1005	983	726	527	339	7874
MEDFORD	0	0	78	372	678	871	918	697	642	432	242	78	5008
PENDLETON	0	0	111	350	711	884	1017	773	617	396	205	63	5127
PORTLAND	25	28	114	335	597	735	825	644	586	396	245	105	4635
ROSEBURG	22	16	105	329	567	713	766	608	570	405	267	123	4491
SALEM	37	31	111	338	594	729	822	647	611	417	273	144	4754
SEXTON SUMMIT	81	81	171	443	666	874	958	809	818	609	465	279	6254
PA. ALLENTOWN	0	0	90	353	693	1045	1116	1002	849	471	167	24	5810
ERIE	0	25	102	391	714	1063	1169	1081	973	585	288	60	6451
HARRISBURG	0	0	63	298	648	992	1085	907	766	396	124	12	5251
PHILADELPHIA	0	0	60	291	621	964	1014	890	744	390	115	12	5101
PITTSBURGH	0	9	105	375	726	1063	1119	1002	874	480	195	39	5987
READING	0	0	54	257	597	939	1001	885	735	372	105	0	4945
SCRANTON	0	19	132	434	762	1104	1156	1028	893	498	195	33	6254
WILLIAMSPORT	0	9	111	375	717	1073	1122	1002	856	468	177	24	5934
R. I. BLOCK IS.	0	16	78	307	594	902	1020	955	877	612	344	99	5804
PROVIDENCE	0	16	96	372	660	1023	1110	988	868	534	236	51	5954
S. C. CHARLESTON	0	0	0	59	282	471	487	389	291	54	0	0	2033
COLUMBIA	0	0	0	84	345	577	570	470	357	81	0	0	2484
FLORENCE	0	0	0	78	315	552	552	459	347	84	0	0	2387
GREENVILLE	0	0	0	112	387	636	648	535	434	120	12	0	2884
SPARTANBURG	0	0	15	130	417	667	663	560	453	144	25	0	3074
S. DAK. HURON	9	12	165	508	1014	1432	1628	1355	1125	600	288	87	8223
RAPID CITY	22	12	165	481	897	1172	1333	1145	1051	615	326	126	7345
SIOUX FALLS	19	25	168	462	972	1361	1544	1285	1082	573	270	78	7839
TENN. BRISTOL	0	0	51	236	573	828	828	700	598	261	68	0	4143
CHATTANOOGA	0	0	18	143	468	698	722	577	453	150	25	0	3254
KNOXVILLE	0	0	30	171	489	725	732	613	493	198	43	0	3494
MEMPHIS	0	0	18	130	447	698	729	585	456	147	22	0	3232
NASHVILLE	0	0	30	158	495	732	778	644	512	189	40	0	3578
OAK RIDGE (CO)	0	0	39	192	531	772	778	669	552	228	56	0	3817
TEX. ABILENE	0	0	0	99	366	586	642	470	347	114	0	0	2624
AMARILLO	0	0	18	205	570	797	877	664	546	252	56	0	3985
AUSTIN	0	0	0	31	225	388	468	325	223	51	0	0	1711
BROWNSVILLE	0	0	0	0	66	149	205	106	74	0	0	0	600
CORPUS CHRISTI	0	0	0	0	120	220	291	174	109	0	0	0	914
DALLAS	0	0	0	62	321	524	601	440	319	90	6	0	2363
EL PASO	0	0	0	84	414	648	685	445	319	105	0	0	2700
FORT WORTH	0	0	0	65	324	536	614	448	319	99	0	0	2405
GALVESTON	0	0	0	0	138	270	350	258	189	30	0	0	1235
HOUSTON	0	0	0	6	183	307	384	288	192	36	0	0	1396
LAREDO	0	0	0	0	105	217	267	134	74	0	0	0	797
LUBBOCK	0	0	18	174	513	744	800	613	484	201	31	0	3578
MIDLAND	0	0	0	87	381	592	651	468	322	90	0	0	2591
PORT ARTHUR	0	0	0	22	207	329	384	274	192	39	0	0	1447
SAN ANGELO	0	0	0	68	318	536	567	412	288	66	0	0	2255
SAN ANTONIO	0	0	0	31	207	363	428	286	195	39	0	0	1549
VICTORIA	0	0	0	6	150	270	344	230	152	21	0	0	1173
WACO	0	0	0	43	270	456	536	389	270	66	0	0	2030
WICHITA FALLS	0	0	0	99	381	632	698	518	378	120	6	0	2832
UTAH MILFORD	0	0	99	443	867	1141	1252	988	822	519	279	87	6497
SALT LAKE CITY	0	0	81	419	849	1082	1172	910	763	459	233	84	6052
WENDOVER	0	0	48	372	822	1091	1178	902	729	408	177	51	5778
VT. BURLINGTON	28	65	207	539	891	1349	1513	1333	1187	714	353	90	8269
VA. CAPE HENRY	0	0	0	112	360	645	694	633	536	246	53	0	3279
LYNCHBURG	0	0	51	223	540	822	849	731	605	267	78	0	4166
NORFOLK	0	0	0	136	408	698	738	655	533	216	37	0	3421
RICHMOND	0	0	36	214	495	784	815	703	546	219	53	0	3865
ROANOKE	0	0	51	229	549	825	834	722	614	261	65	0	4150
WASH. NAT'L AP	0	0	33	217	519	834	871	762	626	288	74	0	4224

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STATE AND STATION	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	ANNUAL
WASH. OLYMPIA	68	71	198	422	636	753	834	675	645	450	307	177	5236
SEATTLE	50	47	129	329	543	657	738	599	577	396	242	117	4424
SEATTLE BOEING	34	40	147	384	624	763	831	655	608	411	242	99	4838
SEATTLE TACOMA	56	62	162	391	633	750	828	678	657	474	295	159	5145
SPOKANE	9	25	168	493	879	1082	1231	980	834	531	288	135	6655
STAMPEDE PASS	273	291	393	701	1008	1178	1287	1075	1085	855	654	483	9283
TATOOSH IS.	295	279	306	406	534	639	713	613	645	525	431	333	5719
WALLA WALLA	0	0	87	310	681	843	986	745	589	342	177	45	4805
YAKIMA	0	12	144	450	828	1039	1163	868	713	435	220	69	5941
W. VA. CHARLESTON	0	0	63	254	591	865	880	770	648	300	96	9	4476
ELKINS	9	25	135	400	729	992	1008	896	791	444	198	48	5675
HUNTINGTON	0	0	63	257	585	856	880	764	636	294	99	12	4446
PARKERSBURG	0	0	60	264	606	905	942	826	691	339	115	6	4754
WIS. GREEN BAY	28	50	174	484	924	1333	1494	1313	1141	654	335	99	8029
LA CROSSE	12	19	153	437	924	1339	1504	1277	1070	540	245	69	7589
MADISON	25	40	174	474	930	1330	1473	1274	1113	618	310	102	7863
MILWAUKEE	43	47	174	471	876	1252	1376	1193	1054	642	372	135	7635
WYO. CASPER	6	16	192	524	942	1169	1290	1084	1020	657	381	129	7410
CHEYENNE	19	31	210	543	924	1101	1228	1056	1011	672	381	102	7278
LANDER	6	19	204	555	1020	1299	1417	1145	1017	654	381	153	7870
SHERIAN	25	31	219	539	948	1200	1355	1154	1054	642	366	150	7683

One of the most practical of weather statistics is the "heating degree day." First devised some 50 years ago, the degree day system has been in quite general use by the heating industry for more than 30 years.

Heating degree days are the number of degrees the daily average tempertaure is below 65°. Normally heating is not required in a building when the outdoor average daily temperature is 65°. Heating degree days are determined by substracting the average daily temperatures below 65° from the base 65°. A day with an average temperature of 50° has 15 heating degree days (65 — 50 = 15) while one with an average temperature of 65° or higher has none.

Several characteristics make the degree day figures especially useful. They are cumulative so that the degree day sum for a period of days represents the total heating load for that period. The relationship between degree days and fuel consumption is linear, i.e., doubling the degree days usually doubles the fuel consumption. Comparing normal seasonal degree days in different locations gives a rough estimate of seasonal fuel consumption. For example, it would require roughly 4½ times as much fuel to heat a building in Chicago, Ill., where the mean annual total heating degree days are about 6,200 than to heat a similar building in New Orleans, La., where the annual total heating degree days are around 1,400. Using degree days has the advantage that the consumption ratios are fairly constant, i.e., the fuel consumed per 100 degree days is about the same whether the 100 degree days occur in only 3 or 4 days or are spread over 7 or 8 days.

The rapid adoption of the degree day system paralleled the spread of automatic fuel systems in the 1930's. Since oil and gas are more costly to store than solid fuels, this places a premium on the scheduling of deliveries and the precise evaluation of use rates and peak demands.

PROTECTING YOUR POCKETBOOK

If there is one characteristic consumers have in common, it is the desire to get one's money's worth on a commercial transaction. In the solar field, there are three main obstacles in satisfying this all-important objective:

1. The consumer's own lack of knowledge and inexperience in this field.
2. Manufacturers who unintentionally build shoddy products and who are too overenthusiastic about their products.
3. Deliberate fraud and misrepresentation.

The best weapon against all three is for the consumer to recognize his or her own limitations and to rely upon competent engineering counsel. "Knowing that one does not know" is the first step toward wisdom, as one old philosopher said.

Though the purpose of this book is to give you some basic guidelines in buying solar, it is not all conclusive. Beyond these guidelines presented herein, and the need for proper engineering counsel, here are some other steps you can take to insure that you get your money's worth in a solar system:

● *Ask for proof that the product will perform as advertised.* The proof could come from an independent laboratory or a university. You should have the report itself, not what the manufacturer states the report claims. Have your engineering consultant go over the report.

● *Examine the warranty carefully.* Remember that according to the law, the manufacturer must state that the warranty is full or limited. If it is limited, know what the limitations are. How long does the warranty last? Are parts, service, and labor covered? Who will provide the service? Does the equipment have to be sent back to the manufacturer for repairs? Make sure you understand the terms of the warranty before you buy. Ask the seller what financial arrangements, such as an escrow account, have been made to honor the warranties. Be sure your engineering counsel not only looks over the warranty, but the design itself to determine whether there are any important omissions.

● *Solar components are like stereo components—some work well together, others don't.* If the system you are purchasing is not sold as a single package by one manufacturer, then you should obtain assurance that the seller has had the professional experience of choosing properly.

● *Ask the man or woman who owns one.* Ask the seller for a list of previous purchasers and their addresses, and then ask the owners about their experiences.

● *Be careful of sellers who use Post Office Box numbers.* Though many legitimate businesses use these outlets as a convenient way to receive bills and orders, a common tactic of the fly-by-night artist is to use a Post Office Box number, operate a territory until the law starts closing in, then move and take a new name in a new territory. Find out from the seller where his place of business is, how long he has been there, and ask for his financial references.

● *Be sure you will know specifically who will service the solar system if something goes wrong.* Don't settle for a response that any plumber or handyman will do.

● *Don't try a do-it-yourself kit, unless you really have a very solid background as a handyman.* One or two mistakes could make a system inoperable and you will have no one to blame but yourself.

● *Remember that what counts with a solar system is the amount of Btu's delivered for the final end use of the system, and that this amount can fluctuate widely.* A very good winter with much sunshine can produce performance levels beyond the manufacturer's projections. Conversely, an unusually bad winter with heavy cloud covers could make the projections drop dramatically. The seller will be working from historical averages. A good guide to performance is whether the season is typical or atypical. If it is typical, and your energy use patterns haven't changed, then the savings projections may have been inaccurate.

● *Don't change your use habits simply because you are getting plenty of free energy.* Conservation of energy still counts if you want to bring your monthly bills down. Don't blame the seller of a solar heating system if you keep your doors open during the middle of wintertime.

● *Don't forget your local consumer office or your Better Business Bureau.* Both may be able to help you determine whether a seller is reputable or not. Check, too, to see whether there is a local volunteer citizens solar organization around. If so, it can probably give you plenty of good advice.

● *If the seller makes verbal claims that are not reflected in the literature handed out, ask him to write those claims down, and to sign his name to it.* Compare what he said with what he wrote. Save that statement.

● *If you have what appears to be a legitimate complaint, notify the local district attorney's office immediately, the Better Business Bureau, and the local consumer protection agency.* Be as specific in your complaint as possible, and give as much documentation as you can.

ANSWERS TO QUESTIONS YOU ALWAYS WANTED TO ASK

Q: Supposing I move out of the house in a year or two. Can I count on appreciation?

A: It depends on two basic factors: if it looks good and if it saves sufficient energy purchases. You should be able to prove whether it works or not in cases of retrofit simply by saving your energy bills, and comparing conventional fuel usage with past bill statements. In cases of new homes, comparisons of operating costs for solar versus conventional homes can be helpful, but not conclusive because of large differences in heat use by different families even in identical homes. Year-to-year differences may also be large, so a call to your energy supplier (gas or electric company or oil supplier) can be helpful in establishing what the relative energy use should have been.

As to eye appeal, that's something else. If it looks good to you and your neighbors, the odds for appreciation are in your favor. But remember, it's the buyer's eye that counts the most.

Q: If I plan on a heating system, should I allow for extra space for storage and collector so that I can later adapt to a cooling unit?

A: Ask your engineering consultant what these extra costs amount to for your particular design. If you are building a new home, and plan to live in it for some time, it will probably be easier to plan now for a cooling system, rather than retrofit later.

Q: Should I buy now or later when improvements in solar technology are sure to take place?

A: There is no doubt that later solar systems will have improvements over present models, and there will not be as much risk for the buyer as there is today. However, costs for tomorrow's solar systems may go higher, and you lose all the money you could have saved from not using expensive conventional fuels. There's something to be said, too, about being a pioneer.

Q: Will I need a humidifier with my solar system?

A: Fundamentally, a solar system replaces "conventional" energy with solar energy. It does not necessarily have any effect upon the need for a humidifier. Many solar systems use a hot water tank for energy storage and the hot water tank may be located within the structure. Generally, if this is the case, the tank should be covered and sealed so that water vapor (humidity) does not escape from the tank into your house in the summertime when it is not wanted. An uncovered tank would help humidify the air in your house in the winter but the "price" paid because of excessive humidity in the summer is generally too high.

Q: How can I contact a reliable solar engineer?

A: One of your best bets is to call a local engineering university and ask to speak to one of the professors about solar energy. Tell the professor you want to hire an advisor who is knowledgeable in the area. Generally, these instructors have a good idea of who is good in a local community. Failing that, contact one of the local engineering societies (such as the American Institute of Architects, the Society of Mechanical Engineers, or the American Society of Heating, Refrigeration, and Air Conditioning Engineers) and ask for a list of engineers who are knowledgeable about solar. When you make contact with those who are on the list, ask for references as to their previous work in the field.

BIBLIOGRAPHY

Criteria For The Preliminary Design Of Solar-Heated Buildings, by Everett M. Barber, Jr. and Donald Watson, A.I.A., 1974. 51 p. $10.00 Sunworks, Inc., Guilford, Connecticut 06437.

Design Input Data For Solar Heating and Cooling, InterTechnology Corporation, Box 340, Warrenton, Virginia 22186, 1975. 21 p.

Energy for the Home, by Peter Clegg, 1975. 252 p. Garden Way Publishing, Charlotte, Vermont 05445. (Lib. of Congress Catalog Card Number: 75-3492; International Standard Book Number: 0-88266-060-9.)

Impact of Energy Developments on the Sheet Metal Industry, by Arnold Cohen, Mary Harlow, Augustus Johnson, Peter Spewak (A study performed by the Mitre Corporation for the Sheet Metal Workers International Association), June 1975, 88 p. The Mitre Corporation, 1820 Dolly Madison Boulevard, McLean, Virginia.

Retrofitting Existing Housing for Energy Conservation: An Economic Analysis, by Stephen R. Petersen, Center for Building Technology, National Bureau of Standards, Washington, D.C. 20234, December 1974, 69 p. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 (Order No. C13.29:2/64). $1.35.

Solar Directory, 1974, by Carolyn Pesko, Environmental Action of Colorado, University of Colorado—Denver, 1100 14th Street, Denver, Colorado 80202, 606 p.

Solar Energy and Shelter Design, by Bruce Anderson, Total Environmental Action, Church Hill, Harrisville, New Hampshire 03450, January 1973. 151 p.

Solar Energy Utilization in Florida, prepared for the Florida Energy Committee by Booz, Allen and Hamilton, Inc., Engineering Consultants, 4733 Bethesda Avenue, Bethesda, Maryland 20014, 1975. 218 p. $3.28.

Solar Heated Buildings—A Brief Survey, 10th Edition, by W. A. Shurcliff, 19 Appleton Street, Cambridge, Massachusetts 02138, Sept. 9, 1975, 148 p. $8.00.

Solar Energy Thermal Processes, by J. A. Duffie and W. A. Beckman, John Wiley & Sons, New York, 1975.

Low Temperature Applications of Solar Energy, by Am. Soc. of Heating, Refrigerating, and Air Conditioning Engineers, New York. (New edition in preparation.)

OTHER SOURCES

Catalog on Solar Energy Heating and Cooling Products,

Catalog on Solar Energy Heating and Cooling Products, Energy Research and Development Administration (Division of Solar Energy in Cooperation with the Department of Housing and Urban Development), October, 1975, ERDA Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830. Catalog No. ER 1.11: ERDA-75, cost $3.80.

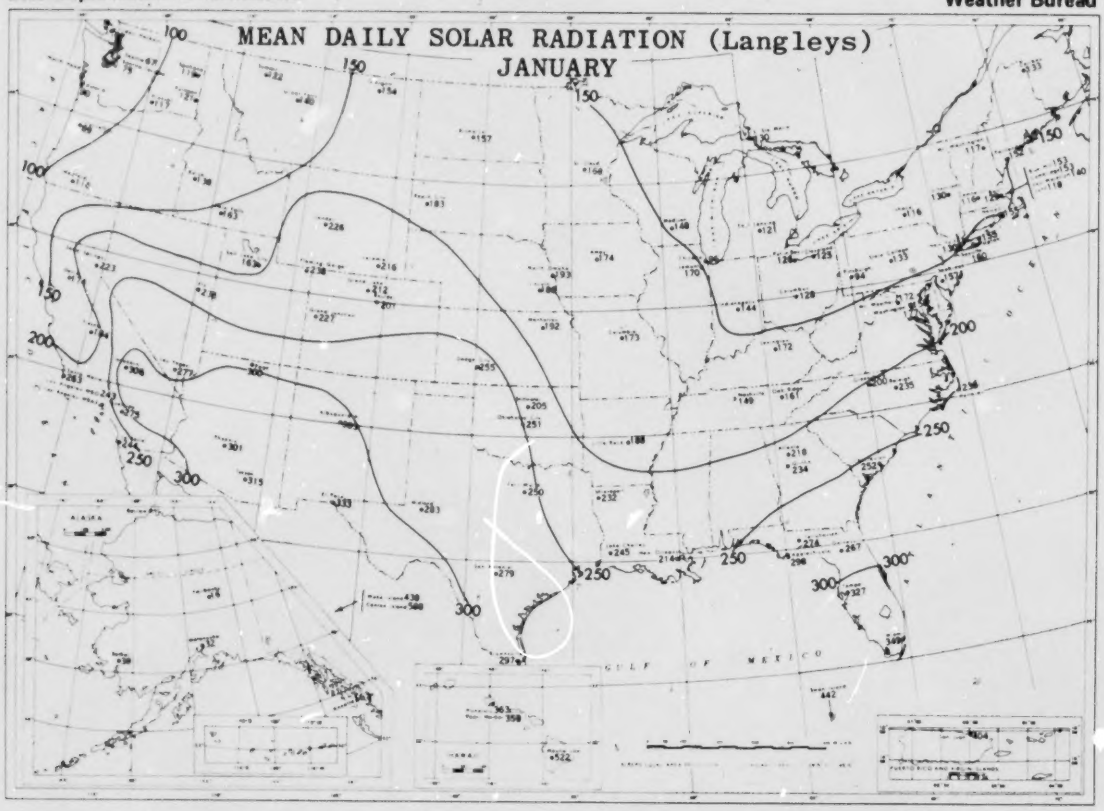
In the Bank or Up the Chimney? A Dollars and Cents Guide to Energy-Saving Home Improvements, Office of Policy Development and Research, Division of Energy, Building Technology, and Standards, U.S. Department of Housing and Urban Development, Washington, D.C. 20410, April 1975, 72 p. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Catalog No. HH 1.6/3: EM 2/3, cost $1.70 per copy.

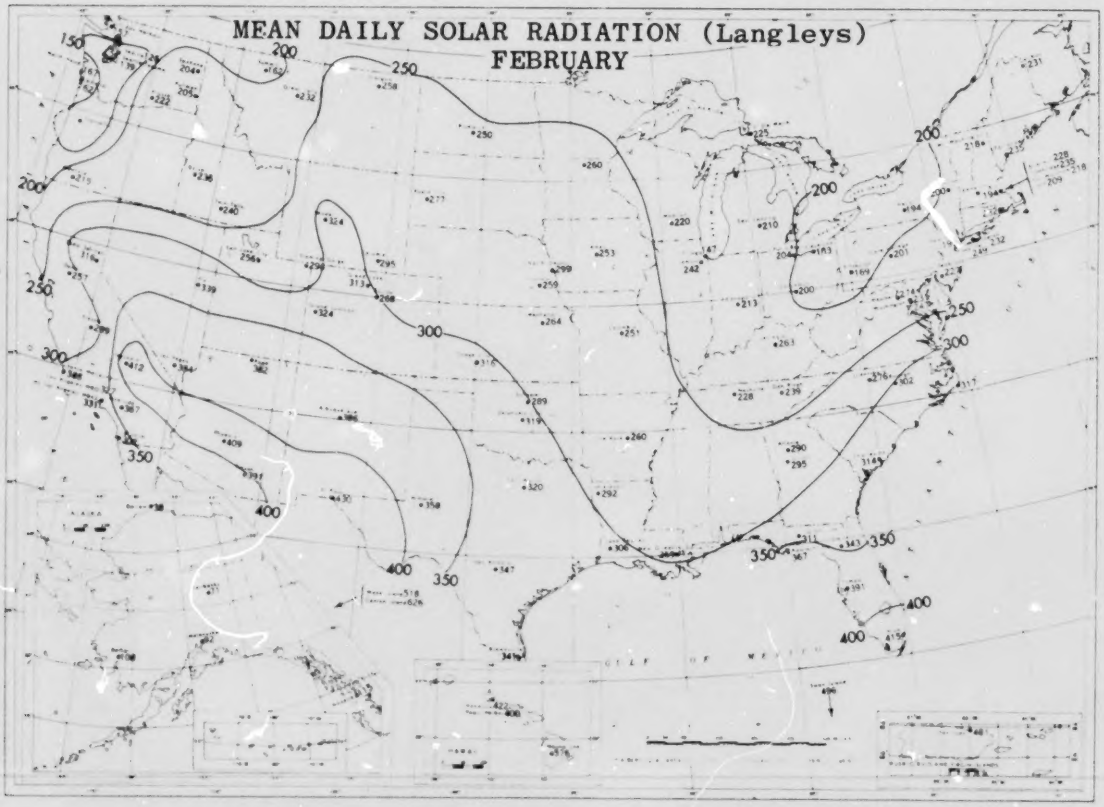
Making the Most of Your Energy Dollars in Home Heating and Cooling, National Bureau of Standards, U.S. Department of Commerce, Washington, D.C. 20234, June 1975, 16 p. Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Catalog No. C13.53: 8, cost 70 cents per copy.

Solar Energy Institute of America Catalog of Products and Services, Solar Energy Institute of America, P.O. Box 9352, Washington, D.C. 20005.

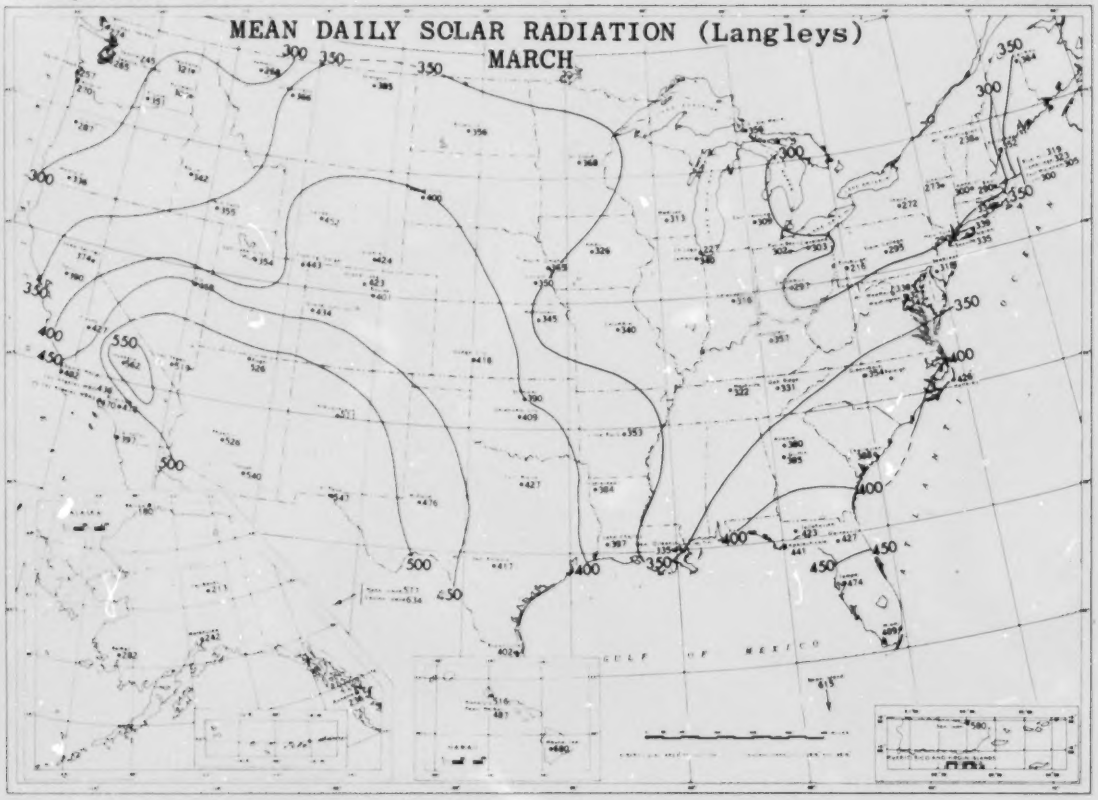
Mean Daily Solar Radiation, Monthly and Annual

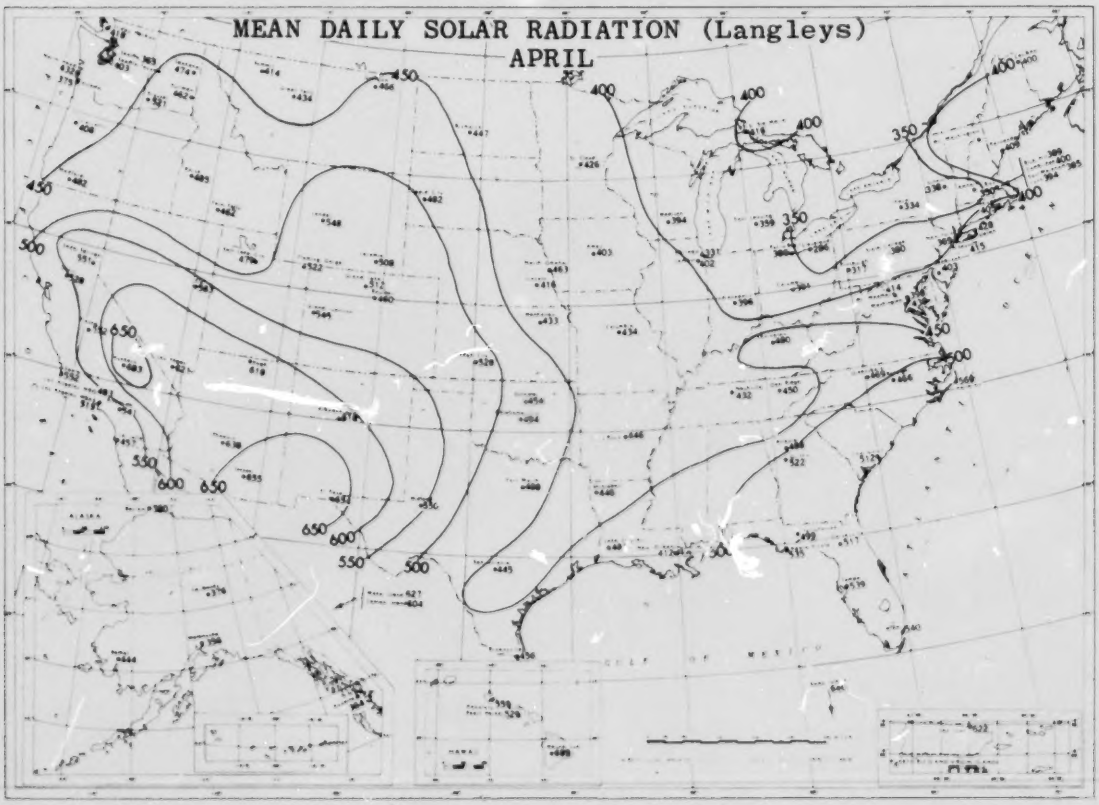
U.S. Department of Commerce — Weather Bureau





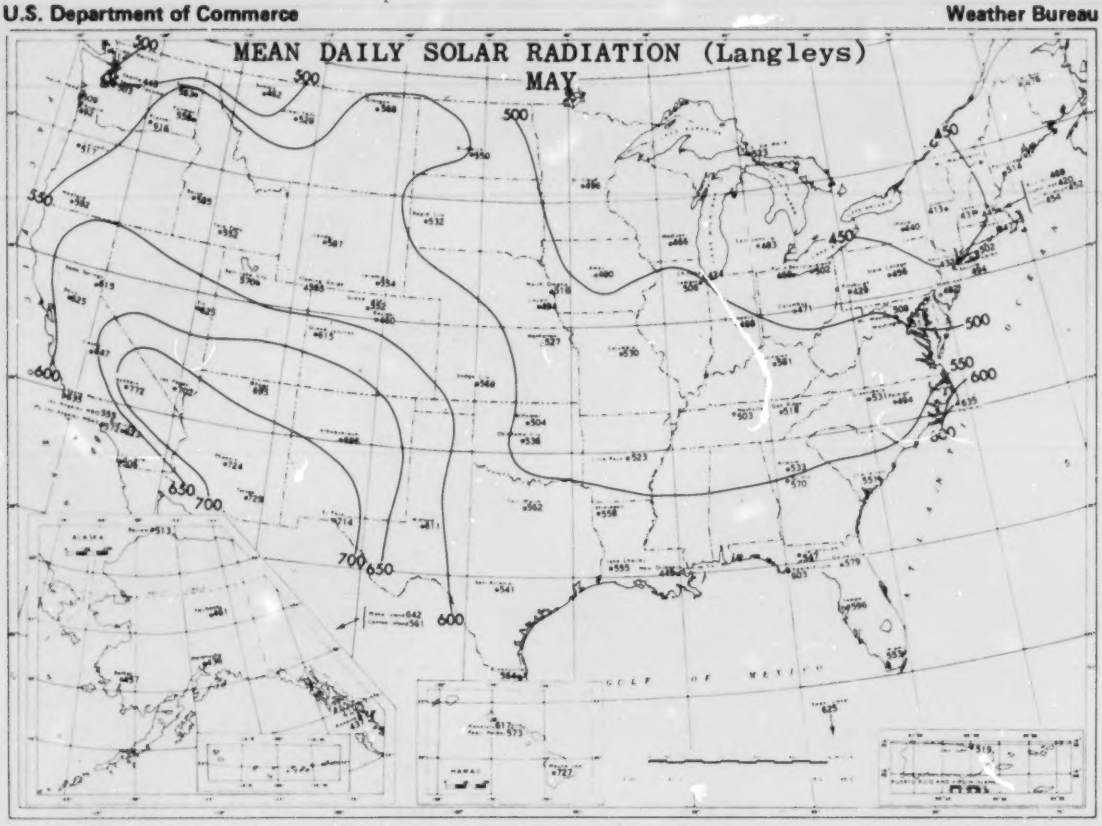
U.S. Department of Commerce Weather Bureau

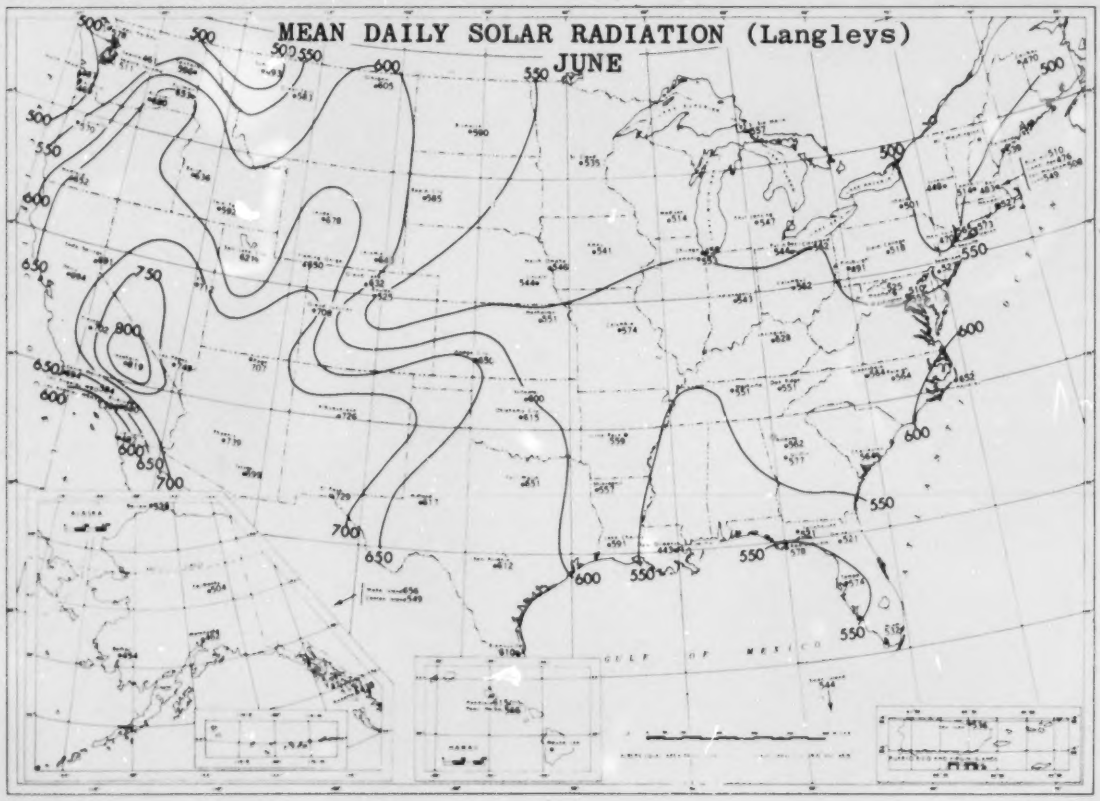




Mean Daily Solar Radiation, Monthly and Annual

U.S. Department of Commerce **Weather Bureau**





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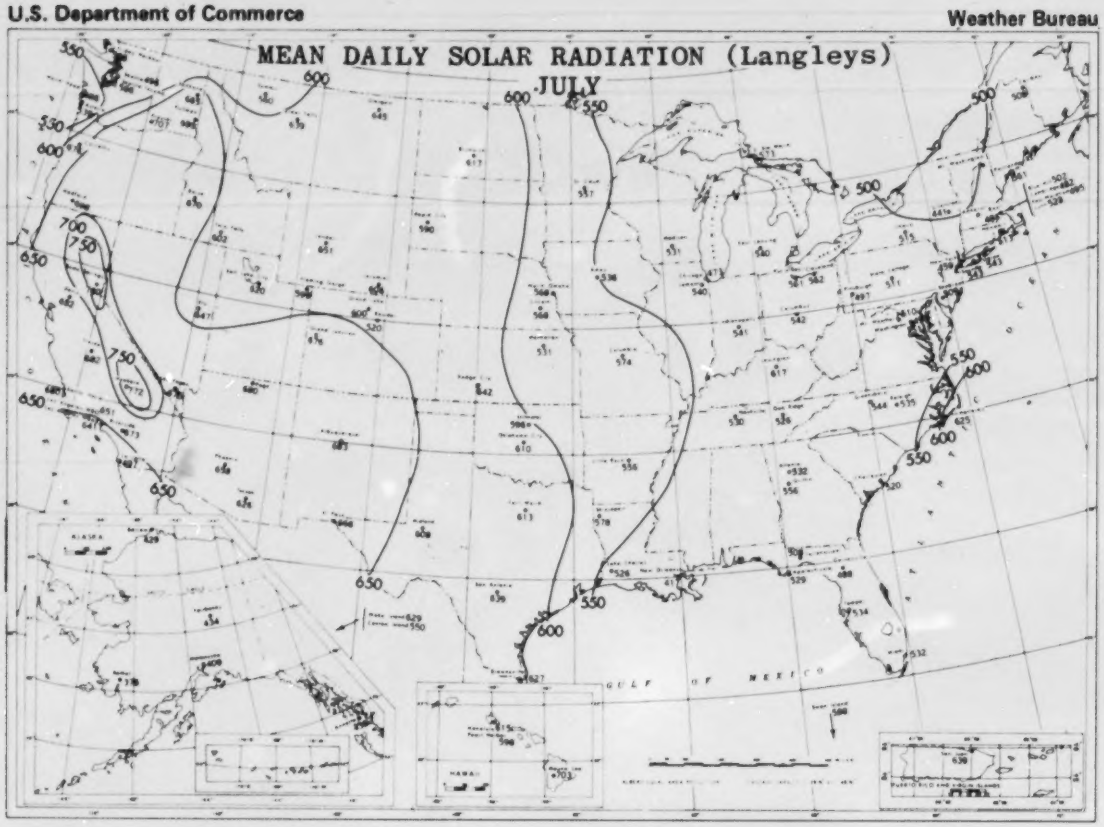

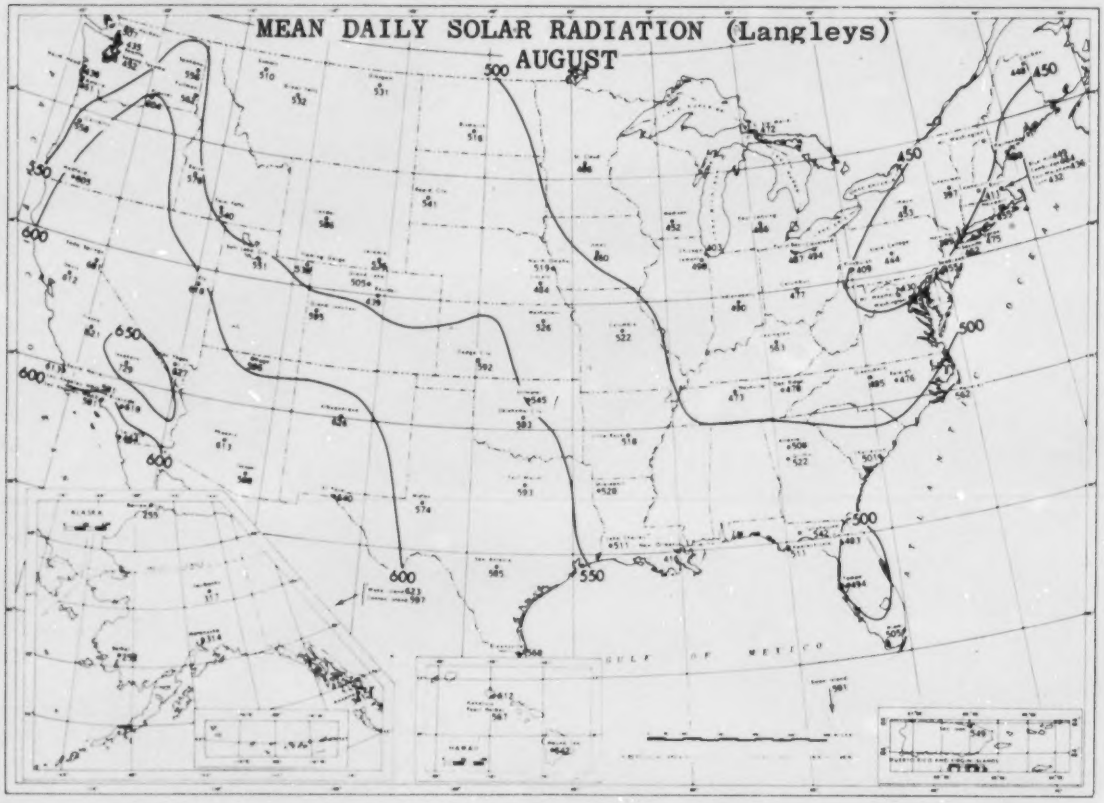

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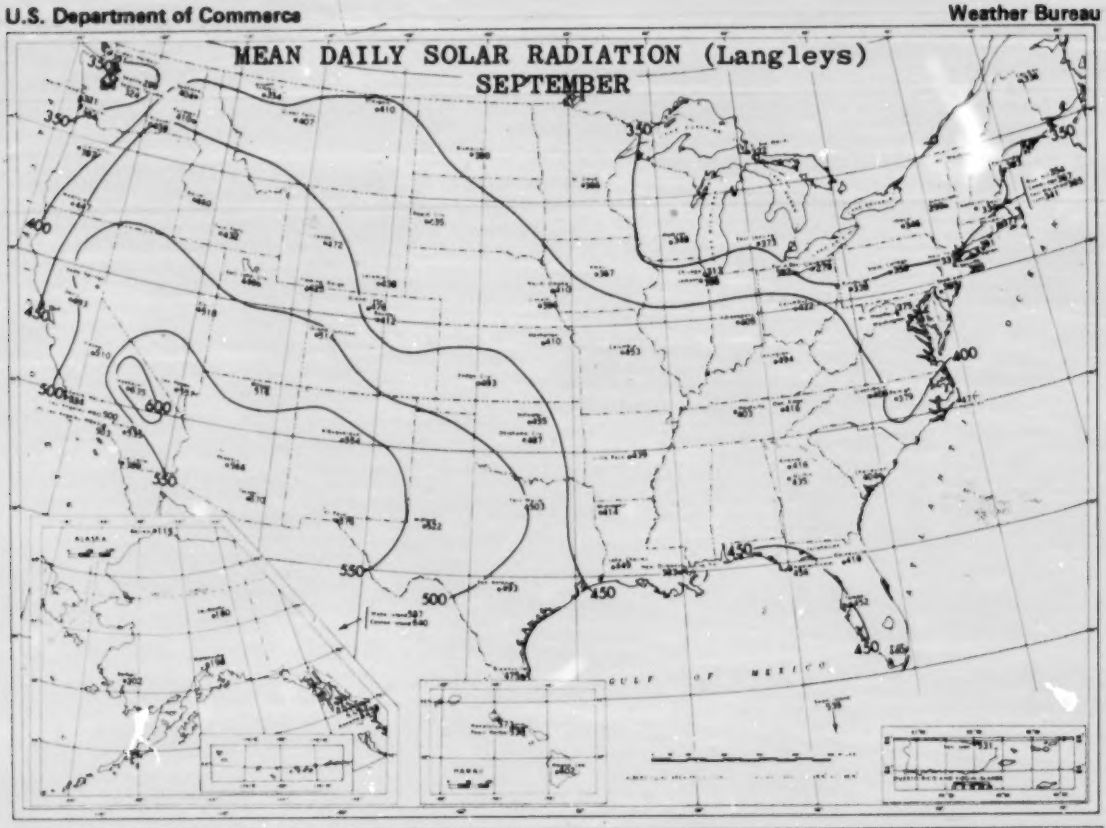

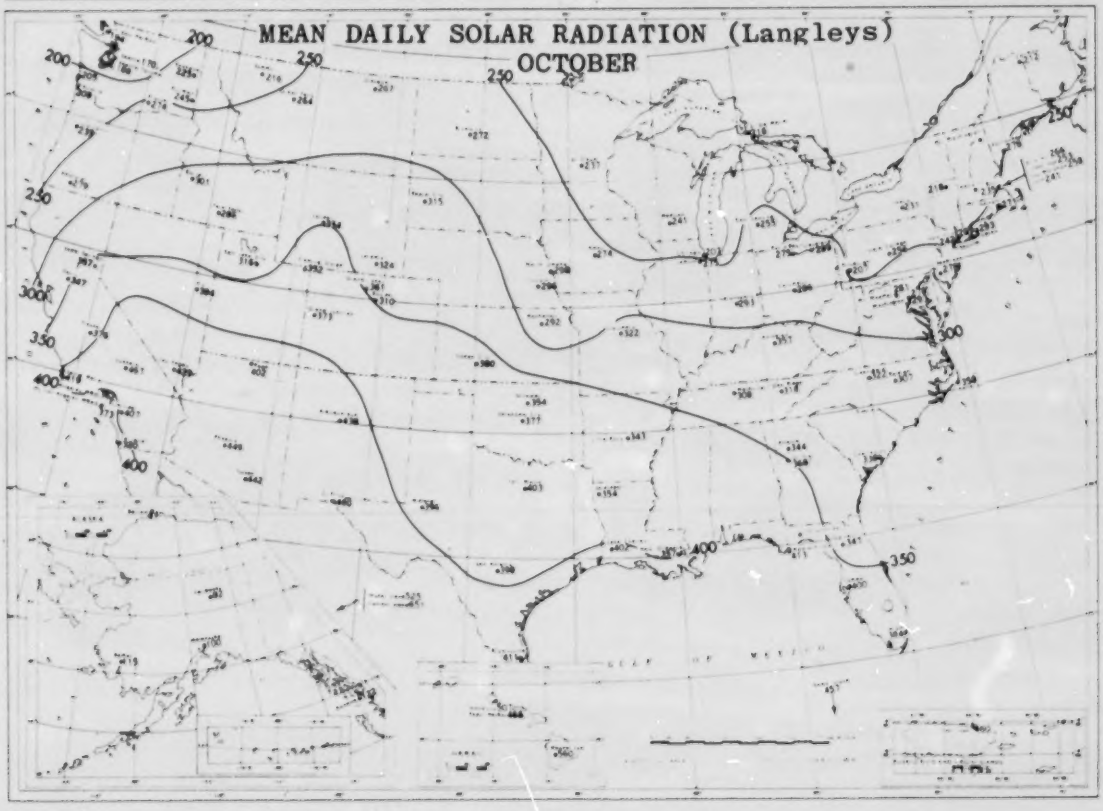

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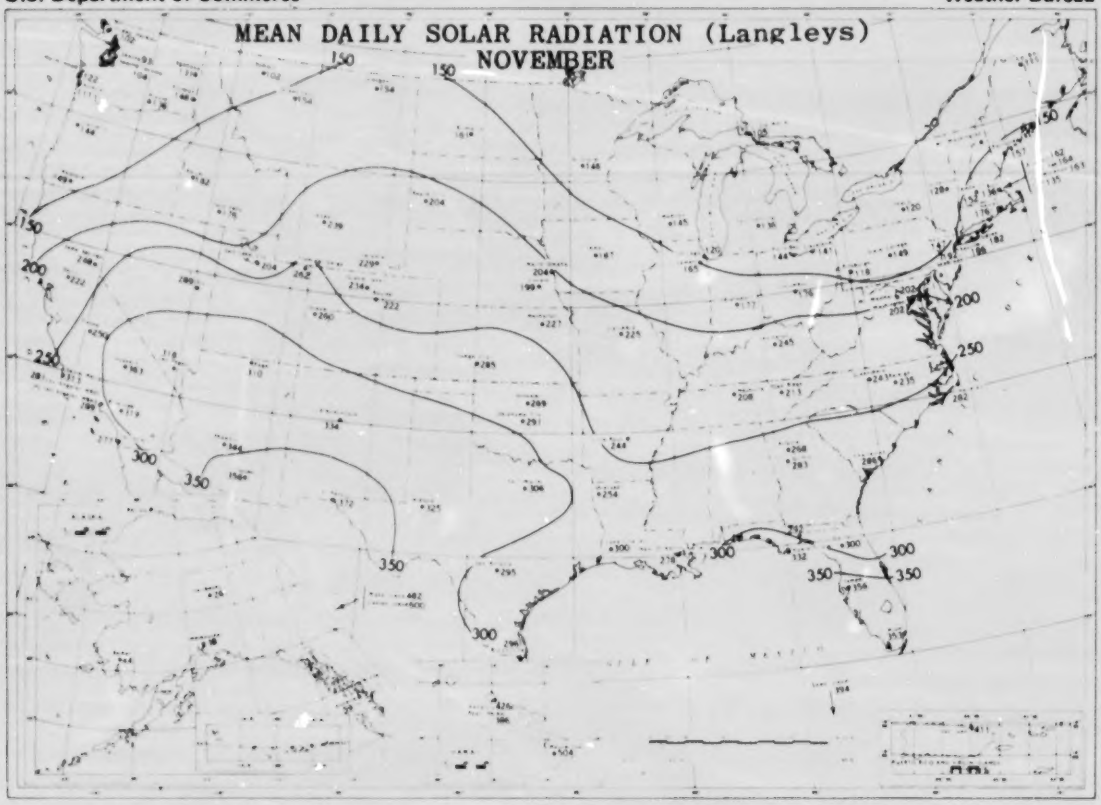

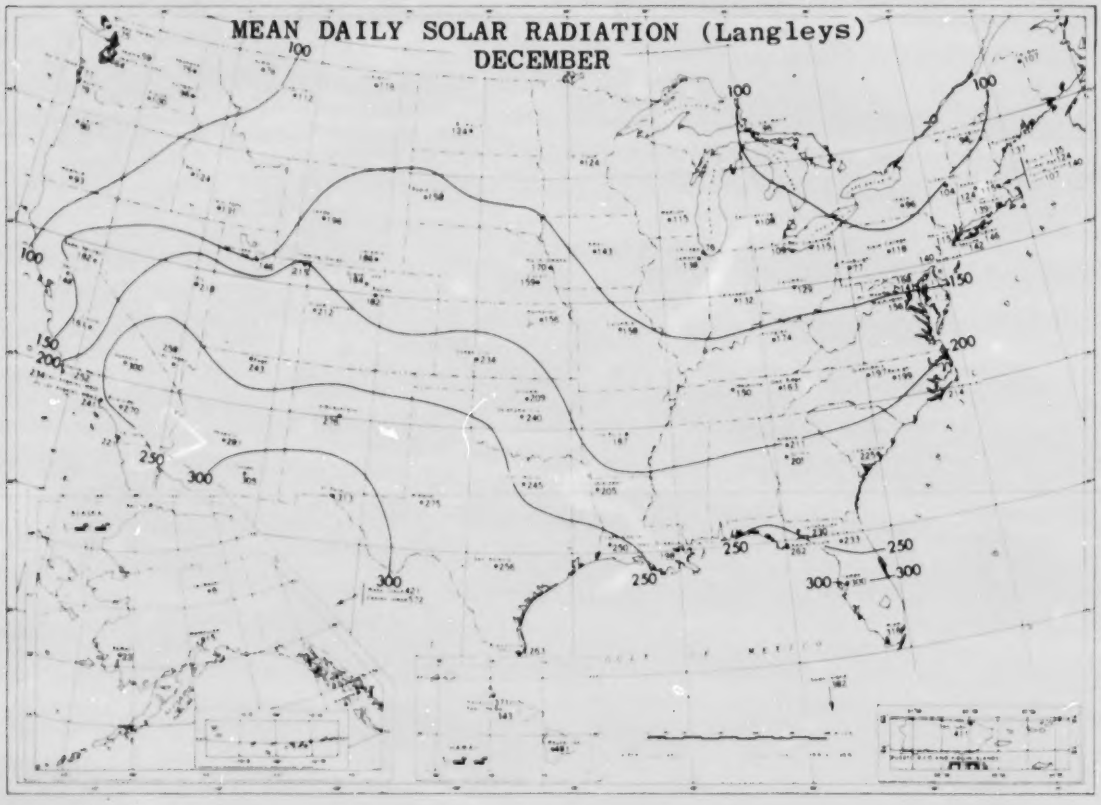

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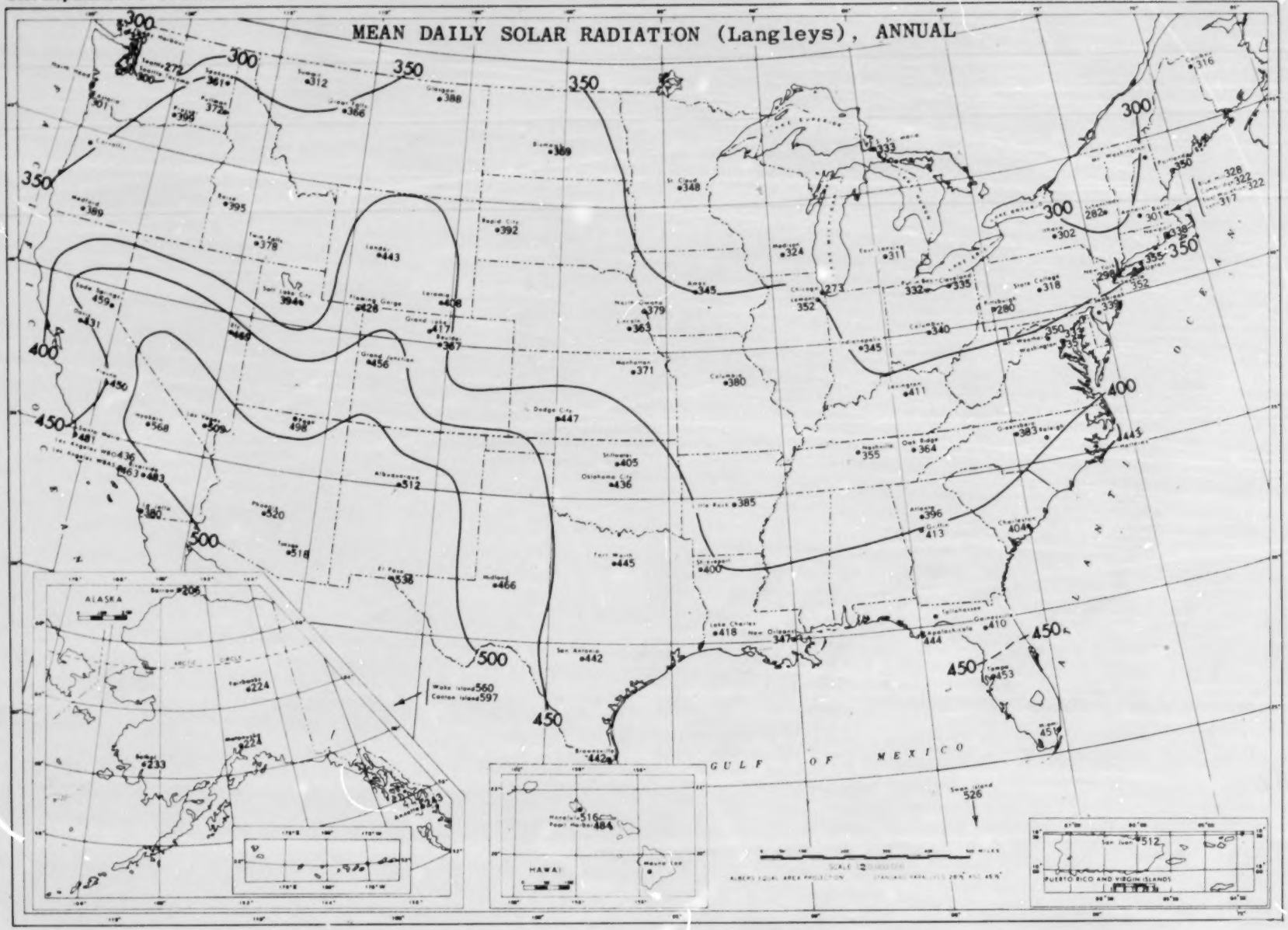
U.S. Department of Commerce

Weather Bureau



These charts and table are based on all usable solar radiation data, direct and diffuse, measured on a horizontal surface and published in the Monthly Weather Review and Climatological Data National Summary through 1962. All data were measured in, or were reduced to, the International Scale of Pyrheliometry, 1956.

Langley is the unit used to denote one gram calorie per square centimeter (1 langley = 1 gm. cal. cm^{-2}).

STATES AND STATIONS	JAN	YRS	FEB	YRS	MAR	YRS	APR	YRS	MAY	YRS	JUNE	YRS	JULY	YRS	AUG	YRS	SEPT	YRS	OCT	YRS	NOV	YRS	DEC	YRS	ANNUAL
ALASKA, Annette	63	6	115	6	236	7	364	7	437	6	438	6	438	6	341	6	258	7	122	7	59	7	41	7	243
Barrow	*		38	8	180	8	380	8	513	8	528	8	429	9	255	10	115	10	41	10	*		*		206
Bethel	38	9	108	10	282	9	444	10	457	10	454	10	376	10	252	10	202	10	115	10	44	9	22	9	233
Fairbanks	16	25	71	27	213	25	376	28	461	28	504	29	434	28	317	29	180	29	82	30	26	26	6	26	224
Matanuska	32	6	92	6	242	4	356	7	436	7	462	6	409	6	314	6	198	6	100	6	38	6	15	7	224
ARIZ., Page	300	2	382	3	526	3	618	2	695	2	707	2	680	3	596	3	516	3	402	3	310	3	243	3	498
Phoenix	301	11	409	11	526	11	638	11	724	11	739	11	658	11	613	11	566	11	449	11	344	11	281	11	520
Tucson	315	5	391	5	540	4	655	5	729	5	699	5	626	6	588	6	570	6	442	6	356	6	305	6	518
ARK., Little Rock	188	9	260	9	353	10	446	9	523	9	559	9	556	8	518	9	439	7	343	8	244	10	187	10	385
CALIFORNIA, Davis	174	18	257	17	390	18	528	18	625	18	694	18	682	18	612	18	493	18	347	19	222	19	148	19	431
Fresno	184	31	289	31	427	31	552	31	647	31	702	32	682	32	621	31	510	31	376	32	250	31	161	32	450
Inyokern (China Lake)	306	11	412	11	562	11	683	11	772	11	819	11	772	11	729	10	635	8	467	9	363	11	300	12	568
LaJolla	244	19	302	18	397	19	457	20	506	19	487	21	497	22	464	22	389	22	320	21	277	20	221	20	380
Los Angeles WBAS	248	10	331	10	470	10	515	10	572	9	596	9	641	9	581	10	503	10	373	10	289	10	241	10	463
Los Angeles WBO	243	9	327	9	436	9	483	9	555	9	584	9	651	9	581	10	500	10	362	10	281	10	234	10	436
Riverside	275	8	367	8	478	9	541	9	623	9	680	9	673	9	618	9	535	9	407	9	319	9	270	9	483
Santa Maria	263	11	346	11	482	11	552	10	635	11	694	11	680	11	613	11	524	11	419	11	313	11	252	11	481
Soda Springs	223	4	316	3	374	4	551	4	615	3	691	4	760	3	681	3	510	3	357	4	248	4	182	3	459
COLO., Boulder	201	4	268	4	401	4	460	4	460	4	525	5	520	5	439	5	412	4	310	4	222	4	182	4	367
Grand Junction	227	9	324	9	434	8	546	8	615	9	708	8	676	8	595	8	514	8	373	10	260	10	212	10	456
Grand Lake (Granby)	212	7	313	7	423	7	512	8	552	8	632	8	600	8	505	7	478	6	361	7	234	6	184	7	417
D. C., Washington (C.O.)	174	3	266	3	344	2	411	2	551	2	494	2	536	2	446	3	375	3	299	3	211	3	166	3	356
American University	158	39	231	39	322	39	398	39	467	39	510	39	496	39	440	38	364	38	278	38	192	39	141	39	333
Silver Hill	177	7	247	6	342	7	438	7	513	7	555	7	511	7	457	7	391	8	293	8	202	7	156	6	357
FLA., Apalachicola	298	10	367	10	441	10	535	10	603	9	578	9	529	9	511	9	456	9	413	10	332	10	262	10	444
Belle Isle	297	10	330	10	412	10	463	10	483	10	464	10	488	11	461	10	400	10	366	11	313	11	291	10	397
Gainesville	267	11	343	10	427	12	517	12	579	12	521	10	488	10	483	8	418	9	347	8	300	10	233	10	410
Miami Airport	349	10	415	9	489	9	540	10	553	10	532	10	532	10	505	10	440	10	384	10	353	10	316	10	451
Tallahassee	274	2	311	2	423	3	499	3	547	3	521	3	508	3	542	2	*		*		292	2	230	2	---
Tampa	327	8	391	8	474	8	539	8	596	8	574	9	534	9	494	9	452	9	400	9	356	9	300	9	453
GA., Atlanta	218	11	290	11	380	11	488	11	533	11	562	11	532	10	508	10	416	10	344	11	268	11	211	11	396
Griffin	234	9	295	9	385	10	522	11	570	11	577	11	556	11	522	11	435	11	368	11	283	11	201	11	413
HAWAII, Honolulu	363	4	422	4	516	4	559	5	617	5	615	5	615	5	612	5	573	5	507	5	426	5	371	5	516
Mauna Loa Obs	522	2	576	2	680	2	689	3	727	3	*		703	3	642	2	602	2	560	2	504	2	481	3	---
Pearl Harbor	359	5	400	4	487	4	529	5	573	5	566	5	598	5	567	5	539	5	466	5	386	5	343	5	484
IDAHO, Boise	138	10	236	9	342	9	485	9	585	10	636	9	670	10	576	10	460	10	301	11	182	11	124	11	395
Twin Falls	163	20	240	20	355	20	462	21	552	20	592	18	602	20	540	20	432	19	286	20	176	20	131	19	378
ILL., Chicago	96	19	147	19	227	19	331	19	424	19	458	18	473	19	403	18	313	19	207	20	120	20	76	20	273
Lemont	170	6	242	6	340	6	402	6	506	6	553	6	540	6	498	6	398	5	275	5	165	5	138	5	352
IND., Indianapolis	144	10	213	10	316	10	396	10	488	9	543	11	541	10	490	11	405	11	293	11	177	11	132	11	345
IOWA, Ames	174	5	253	5	326	5	403	5	480	5	541	5	436	6	460	6	367	6	274	7	187	7	143	7	345
KANS., Dodge City	255	7	316	7	418	7	528	7	568	7	650	7	642	8	592	9	493	9	380	9	285	10	234	10	447
Manhattan	192	3	264	3	345	3	433	3	527	4	551	4	531	4	526	4	410	4	292	4	227	4	156	4	371
KY., Lexington	172	9	263	9	357	10	480	10	581	10	628	9	617	10	563	10	494	10	357	9	245	9	174	11	411
LA., Lake Charles	245	11	306	11	397	11	481	11	555	11	591	11	526	11	511	11	449	11	402	11	300	10	250	10	418
New Orleans	214	14	259	14	335	15	412	16	449	14	443	13	417	15	416	15	383	15	357	13	278	13	198	14	347
Shreveport	232	3	292	3	384	3	446	4	558	4	557	4	578	4	528	4	414	4	354	4	254	4	205	4	400
MAINE, Caribou	133	8	231	9	364	8	400	10	476	10	470	10	508	11	448	11	336	11	212	11	111	11	107	9	316
Portland	152	7	235	8	351	7	409	8	514	9	539	9	561	9	488	8	383	7	278	9	157	8	137	9	350
MASS., Amherst	116	2	*		30	2	*		431	2	514	2	*		---		---		---		152	2	124	2	---
Blue Hill	153	27	228	27	319	26	389	26	469	27	510	27	502	26	449	27	354	28	266	28	162	28	135	28	328
Boston	129	16	194	17	290	17	350	17	445	16	483	16	486	16	411	16	334	17	235	16	136	16	115	15	301
Cambridge	153	4	235	3	323	3	400	3	420	3	476	3	482	4	464	4	367	4	253	4	164	4	124	4	322
East Wareham	140	13	218	13	305	12	385	14	452	14	508	14	495	14	436	14	365	13	258	14	163	14	140	13	322
Lynn	118	2	209	2	300	2	394	2	454	2	549	4	528	4	432	3	341	2	241	3	135	3	107	3	317
MICH., East Lansing	121	10	210	11	309	11	359	11	483	10	547	11	540	11	466	11	373	11	255	11	136	11	108	11	311
Sault Ste. Marie	130	10	225	9	356	10	416	10	523	10	557	11	573	11	472	10	322	10	216	9	105	9	96	9	333
MINN., St. Cloud	168	8	260	8	368	8	426	8	496	8	535	8	557	9	486	8	366	8	237	7	146	8	124	8	348
MO., Columbia (C. O.)	173	10	251	10	340	11	434	11	530	11	574	11	574	10	522	10	453	10	322	10	225	10	158	9	380
University of Missouri	166	5	248	6	324	6	429	6	501	6	560	6	583	6	509	6	417	6	324	5	177	5	146	5	365
MONT., Glasgow	154	6	258	8	385	7	466	8	568	8	605	8	645	9	531	10	410	10	267	8	154	8	116	7	388
Great Falls	140	8	232	9	366	9	434	8	528	8	583	8	639	9	532	9	407	10	264	10	154	10	112	10	366
Summit	122	3	162	2	268	3	414	3	462	3	493	3	560	2	510	2	354	2	216	2	102	2	76	2	312
NEBR., Lincoln	188	39	259	39	350	39	416	39	494	40	544	38	568	38	484	38	396	38	296	36	199	40	159	39	363
North Omaha	193	3	299	3	365	3	463	3	516	3	546	4	568	4	519	4	410	4	298	4	204	4	170	4	379

STATES AND STATIONS	JAN	YRS	FEB	YRS	MAR	YRS	APR	YRS	MAY	YRS	JUNE	YRS	JULY	YRS	AUG	YRS	SEPT	YRS	OCT	YRS	NOV	YRS	DEC	YRS	ANNUAL
NEV.. Ely	236	7	339	9	468	9	563	9	625	10	712	10	647	11	618	11	518	11	394	10	289	10	218	10	469
Las Vegas	277	11	384	11	519	11	621	11	702	11	748	10	675	11	627	11	551	11	429	11	318	11	258	11	509
N. J.. Seabrook	157	8	227	8	318	8	403	8	482	9	527	8	509	8	455	9	385	9	278	7	192	8	140	8	339
N. H.. Mt. Washington	117	2	218	2	238	2	•		•		•		---		---		•		•		•		96	2	---
N. Mex.. Albuquerque	303	13	386	13	511	13	618	13	686	13	726	13	683	12	626	13	554	14	438	15	334	15	276	14	512
N. Y.. Ithaca	116	22	194	21	272	23	334	23	440	24	501	23	515	23	453	23	346	21	231	22	120	23	96	23	302
N. Y. Central Park	130	34	199	34	290	33	369	35	432	35	470	34	459	35	389	35	331	36	242	36	147	36	115	35	298
Sayville	160	11	249	11	335	10	415	10	494	10	565	10	543	10	462	10	385	10	289	10	186	10	142	11	352
Schenectady	130	8	200	9	273	9	338	9	413	9	448	8	441	8	397	8	299	8	218	8	128	8	104	8	282
Upton	155	8	232	8	339	8	428	8	502	8	573	8	543	7	475	7	391	7	293	6	182	7	146	7	355
N. C.. Greensboro	200	7	276	9	354	9	469	9	531	10	564	10	544	10	485	10	406	10	322	10	243	10	197	8	383
Hatteras	238	10	317	9	426	8	569	9	635	10	652	10	625	10	562	11	471	11	358	11	282	11	214	11	443
Raleigh	235	3	302	2	•		466	3	494	2	564	2	535	3	476	3	379	3	307	3	235	3	199	3	---
N. D.. Bismarck	157	7	250	8	356	6	447	8	550	8	590	9	617	10	516	11	390	11	272	11	161	10	124	10	369
OHIO.. Cleveland	125	6	183	6	303	7	286	8	502	8	562	8	562	8	494	8	278	8	289	9	141	9	115	7	335
Columbus	128	7	200	7	297	7	391	7	471	6	562	4	542	5	477	4	422	4	286	4	176	4	129	5	340
Put-in-Bay	126	10	204	9	302	10	386	11	468	11	544	11	561	10	487	10	382	11	275	11	144	11	109	11	332
OKLA.. Oklahoma City	251	10	319	10	409	9	494	10	536	10	615	7	610	8	593	8	487	9	377	10	291	9	240	9	436
Stillwater	205	8	289	8	390	9	454	9	504	9	600	10	596	10	545	10	455	11	354	10	269	9	209	8	405
OREG.. Astoria	90	7	162	8	270	8	375	8	492	8	469	8	539	8	461	7	354	7	209	8	111	8	79	8	301
Corvallis	89	2	•		287	3	406	3	517	3	570	3	676	4	558	4	397	4	235	4	144	4	80	4	---
Medford	116	11	215	11	336	11	482	11	592	11	652	11	698	10	605	11	447	11	279	11	149	11	93	11	389
PA.. Pittsburgh	94	6	169	5	216	6	317	6	429	6	491	6	497	7	409	6	339	6	207	5	118	6	77	5	280
State College	133	19	201	19	295	20	380	20	456	20	518	20	511	20	444	20	358	20	256	20	149	20	118	20	318
R. I.. Newport	155	23	232	22	334	23	405	23	477	23	527	24	513	24	455	24	377	24	271	24	176	24	139	24	338
S. C.. Charleston	252	11	314	11	388	11	512	11	551	11	564	11	520	11	501	11	404	11	338	11	286	11	225	11	404
S. D.. Rapid City	183	11	277	11	400	11	482	11	532	11	585	11	590	11	541	11	435	11	315	10	204	10	158	10	392
TENN.. Nashville	149	18	228	19	322	19	432	19	503	18	551	18	530	17	473	17	403	17	308	19	208	18	150	19	355
Oak Ridge	161	11	239	11	331	11	450	11	518	11	551	11	526	11	478	11	416	11	318	11	213	10	163	11	364
TEXAS.. Brownsville	297	10	341	10	402	10	456	11	564	10	610	9	627	8	568	11	475	11	411	11	296	11	263	10	442
El Paso	333	11	430	11	547	10	654	11	714	11	729	11	666	11	640	10	576	11	460	11	372	11	313	11	536
Ft. Worth	250	11	320	11	427	11	488	11	562	11	651	11	613	11	593	11	503	11	403	11	306	11	245	9	445
Midland	283	7	358	8	476	9	550	8	611	8	617	8	608	7	574	8	522	9	396	9	325	8	275	8	466
San Antonio	279	9	347	9	417	9	445	9	541	9	612	9	639	9	585	9	493	10	398	10	295	10	256	8	442
UTAH.. Flaming Gorge	238	2	298	2	443	2	522	2	565	2	650	2	599	3	538	3	425	3	352	3	262	3	215	3	426
Salt Lake City	163	8	256	8	354	8	479	8	570	7	621	7	620	6	551	7	446	8	316	8	204	8	146	9	394
VA.. Mt. Weather	172	2	274	2	338	2	414	2	508	2	525	3	510	3	430	3	375	3	281	2	202	2	168	2	350
WASH.. North Head	•		167	2	257	3	432	2	509	3	487	3	486	3	436	3	321	3	205	3	122	3	77	3	---
Friday Harbor	87	8	157	7	274	8	418	8	514	9	578	10	586	10	507	11	351	8	194	10	102	10	75	8	320
Prosser	117	4	222	4	351	4	521	5	616	4	680	4	707	4	604	4	453	4	274	4	136	4	100	4	399
Pullman	121	4	205	2	304	2	462	2	558	4	653	5	699	5	562	4	410	4	245	5	146	5	96	5	372
University of Washington	67	9	126	9	245	10	364	9	445	10	461	10	496	11	435	10	299	8	170	9	93	9	59	9	272
Seattle-Tacoma	75	9	139	9	265	9	403	9	503	9	511	9	566	9	452	10	324	10	188	10	104	9	64	10	300
Spokane	119	8	204	8	321	8	474	9	563	9	596	9	665	9	556	9	404	10	225	9	131	9	75	7	361
WIS.. Madison *	148	46	220	46	313	45	394	47	466	47	514	47	531	47	452	47	348	47	241	47	145	44	115	46	324
WYO.. Lander	226	8	324	9	452	9	548	11	587	11	678	11	651	11	586	10	472	8	354	9	239	9	196	9	443
Laramie	216	3	295	3	424	3	508	3	554	3	643	3	606	3	536	3	438	3	324	3	229	3	186	4	408
ISLAND STATIONS																									
Canton Island	588	9	626	7	634	7	604	9	561	9	549	8	550	9	597	9	640	9	651	9	600	8	572	8	597
San Juan, P. R.	404	5	481	4	580	4	622	4	519	5	536	6	639	5	549	6	531	6	460	6	411	6	411	6	512
Swan Island	442	6	496	7	615	6	646	6	625	6	544	8	588	8	591	7	535	8	457	7	394	8	382	8	526
Wake Island	438	7	518	7	577	7	627	7	642	8	656	6	629	7	623	7	587	6	525	7	482	7	421	7	560

NOTES:

* Denotes only one year of data for the month -- no means computed.

--- No data for the month (or incomplete data for the year).

Barrow is in darkness during the winter months.

* Madison data after 1957 not used due to exposure influences.

‡ Riverside data prior to March 1952 not used-instrumental discrepancies.

Langley is the unit used to denote one gram calorie per square centimeter.

The Solar User's Return on His Investment

Question: What "Return on Investment" may the consumer expect from his purchase of solar equipment—in 5 years? In 10 years?

To answer this question, we must consider a number of factors:

Future Inflation. Most economists expect that inflation will continue over the next decade at a rate of at least 5 percent per year. Basically, this means that the value of property acquired currently will appreciate over a period of time.

Reduction in the Cost of Solar Equipment. Production of solar equipment is still on a modest scale. Many of the producers of the equipment expect that, as volume increases and as further product development takes place, the cost of the equipment *without considering inflation* may decrease.

These two factors offset one another, and to be conservative, we might assume that the price of a solar installation will not increase in the future; therefore, the value of an installation made today will not "appreciate" because of inflation. (If the producers were not able to "hold the line" on cost, equipment bought today would appreciate in value and the purchaser's return on his investment would increase correspondingly.)

Depreciation. Good solar equipment should have a 25-year life. At the end of 5 years, 20 percent of the useful life of the equipment would have been used up, and 40 percent would have been used up at the end of 10 years.

Effect on Resale Value of a Residence. Since the "average" individual moves frequently, which involves resale of his present home, it is important to consider the effect of previously installed solar equipment on the resale value of the home. Most economists agree that the cost of "conventional" energy will rise more rapidly than the general rate of inflation in the future. This means that the rate at which solar equipment saves money for the user will become greater as time goes on and that the "pay out" to the user 5 or 10 years from now will be materially better than it is today. (Please refer to the pay out tables appearing on pages through .) This should make a residence with a solar system already installed attractive to the next buyer. The next buyer would compare the price of a solar-equipped house with the total potential cost of an unequipped house (including the cost of retrofitting it with solar equipment). It will always cost more to retrofit a solar system to a previously built house than to incorporate a solar system in a new house. The extra cost of retrofitting tends to become an element of "appreciation" in the value of the previously equipped house. In the examples presented below, we have made two sets of calculations. One is based upon ignoring this element of appreciation. The other is based upon the assumption that retrofitting an existing house would cost 20 percent more than the cost of an installation made at the time the house was built.

Case 1. A 75 square foot solar water heater is installed on the East Coast as an alternative to the use of electricity for water heating. The original cost is estimated at $1,200. Without "appreciation," its value after 5 years is $960 and after 10 years, it is $720. With "appreciation," its value is $1,152 after 5 years and $864 after 10 years. In 5 years, it would have saved $643 if the current cost of electricity was 3.5¢ per kWh and this cost increased at 7.5 percent per year. Without considering "appreciation," the original value has depreciated by $240. If we subtract this figure from the 5-year savings of $643, we find that the "Return on Investment" is $403, which is 33.6 percent of the original investment. If we consider appreciation, the reduction in value is only $48 and the Return on Investment is $595 in the first 5 years, which is 49.6 percent.

Savings in 10 years are substantially larger—$1,561. Again, ignoring "appreciation," the depreciation in 10 years is $480; and if we subtract this from the total savings, the Return on Investment in 10 years is $1,081 or 90 per cent of the original cost. If we include appreciation in our figures, we only deduct $336 from the 10 year savings, leaving a total Return on Investment of $1,225 to the user, which is a little over 100 percent of the first cost.

If the next buyer pays the "appreciated" value for the solar installation when the solar equipped house is sold to him, his pay out time becomes quite rapid. If he pays $1,152 after 5 years, because of the continuously increasing cost of electricity his cumulative savings will equal the $1,152 price in only 4.7 years. The pay out for the second owner becomes even better after 10 years. If the price he pays is the appreciated value of $864, his savings will

equal the price he paid in only 3.8 years. Obviously, resale of the solar equipped house to the second buyer should represent a real "bargain" to him.

Case 2. A 50-square-foot solar water heater installed in Los Angeles as an alternative to electricity, with the current price of electricity being 3¢ per kWh:

Original Cost:	$900	
Value after 5 years without "appreciation":	$720	
with "appreciation":	$778	
Value after 10 years without "appreciation":	$540	
with "appreciation":	$583	
Savings in 5 years:	$569	
Savings in 10 years:	$1,382	
Savings less loss in value without "appreciation" after 5 years:	$389	(43.2%)
with "appreciation":	$447	(49.7%)
Savings less loss in value without "appreciation" in 10 years:	$1,122	(124.7%)
with "appreciation":	$1,065	(118.3%)

Case 3. A 50-square-foot solar water heater installed in Dallas as an alternative to natural gas currently available at 17.5¢ per therm:

Original Cost:	$900
Value after 5 years without "appreciation":	$720
with "appreciation":	$778
Value after 10 years without "appreciation":	$540
with "appreciation":	$583
Savings in 5 years:	$199
Savings in 10 years:	$519

Without considering appreciation, savings in 5 years are $19 more than depreciation and Return on Investment is 2 percent. With appreciation, return is $82 or 9.1 percent. This is not a very good return. However, after 10 years, even without appreciation, return is $159 or 17.7 percent of the original investment and with appreciation, it is $202 (22.4 percent).

Similar calculations may be made for other alternatives. In general, they show that return to the original purchaser in 5 or 10 years is good to excellent when electric heat or electric hot water is the alternative; reasonably good when oil is the alternative; and only fair where low cost natural gas is still available and remains available in the future.

SOLAR SYSTEM ECONOMICS

About Tables 1 through 5

1. They are intended to illustrate the economics of Solar systems under "typical" conditions in various parts of the United States.
2. Water heater calculations are based on "typical" hot water use by an average family of four.
3. Space heating calculations are based on a 1,500-square-foot single-family residence which is of "typical" construction (varies from one area to another).
4. Electricity, oil, and gas prices used cover the ranges encountered in each area. They are current prices. In calculating future savings, it was forecast that electricity prices would escalate at 7.5 percent per year (5 percent inflation + 2.5 percent). Gas and oil prices were forecast to escalate at 10 percent per year.
5. Pay out time is the time required for cumulative savings to equal first cost.

Table 1.—The economics of "standard" size solar hot water heaters vs. electric hot water heaters

Region/ system size	Solar, pct of hot water	Solar system cost ($)	Pay out time, years (electricity)		
			3¢/kWh	3½¢/kWh	4¢/kWh
East Coast					
(N.Y., Boston, Washington)					
50 ft² system	47	900	8.9	8.0	7.2
75	60	1,200	9.2	8.2	7.4
100	72	1,500	9.5	8.5	7.7
South Florida					
(Miami)					
50 ft² system	69	900	6.7	5.8	5.3
Upper Midwest					
(Chicago - Omaha)					
50 ft² system	54	900	8.1	7.1	6.4
75	69	1,200	8.3	7.4	6.7
100	84	1,500	8.5	7.5	6.8
Lower Midwest					
(St. Louis - Nashville)					
50 ft² system	51	900	8.4	7.5	6.7
75	65	1,200	8.7	7.7	7.0
100	79	1,500	8.9	7.9	7.1
Southwest					
(Dallas)					
50 ft² system	62	900	7.4	6.4	5.7
75	84	1,200	7.1	6.3	5.7
Desert Southwest					
50 ft² system	80	900	7.1	6.3	5.7
Southern California					
(Los Angeles)					
50 ft² system	62	900	7.4	6.4	5.7
75	84	1,200	7.1	6.3	5.7

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Table 2—The economics of "standard" size solar hot water heaters vs. gas hot water heaters

Region/ system size	Solar, pct of hot water	Solar system cost ($)	Pay out time, years (gas) 12.5¢/ Therm	15¢/ Therm	17.5¢/ Therm	20¢/ Therm
East Coast						
(N Y . Boston Washington)						
50 ft² system	47	900	19 0	17 4	16 1	15 0
75	60	1,200	19 4	17 8	16 5	15 4
100	72	1,500	19 7	18 1	16 8	15 7
South Florida						
(Miami)						
50 ft² system	69	900	15 7	14 3	13 1	12 1
Upper Midwest						
(Chicago - Omaha)						
50 ft² system	54	900	17 8	16 2	15 0	13 9
75	69	1,200	18 1	16 6	15 3	14 3
100	84	1,500	18 4	16 8	15 5	14 5
Lower Midwest						
(St Louis - Nashville)						
50 ft² system	51	900	18 3	16 7	15 4	14 4
75	65	1,200	18 7	17 1	15 8	14 7
100	79	1,500	18 [illegible]	17 3	16 0	15 0
Southwest						
(Dallas)						
50 ft² system	62	900	16 6	15 1	13 9	12 9
75	84	1,200	16 5	15 0	13 8	12 8
Desert Southwest						
50 ft² system	80	900	14 5	13 1	12 0	11 1
Southern California						
(Los Angeles)						
50 ft² system	62	900	16 6	15 1	13 9	12 9
75	84	1,200	16 5	15 0	13 8	12 8

Table 3.—The economics of solar space heating plus solar hot water heating vs. oil heat plus electric hot water heat

Region	Solar system cost ($)	Pay out time, years			
		[1]3¢/kWh [2]40¢/Gal	[1]3½¢/kWh [2]43¢/Gal	[1]4¢/kWh [2]45¢/Gal	[1]5¢/kWh [2]45¢/Gal
East Coast - Boston					
40% Solar	4,875	12.1	11.4	10.7	-
50% Solar	6,750	12.6	11.8	11.2	-
East Coast - New York					
40% Solar	4,700	13.0	12.1	11.4	10.5
50% Solar	6,800	14.4	13.5	12.8	11.9
East Coast - Washington					
40% Solar	3,475	10.4	9.6	9.0	-
50% Solar	5,300	12.0	11.2	10.5	-
Upper Midwest					
(Omaha - Chicago)					
40% Solar	3,200	9.2	8.5	8.0	-
50% Solar	4,825	10.6	9.8	9.3	-
Lower Midwest					
(St. Louis - Nashville)					
40% Solar	3,275	10.8	10.0	9.3	-
50% Solar	4,825	12.3	11.4	11.0	-
Southwest					
(Dallas)					
40% Solar	2,200	9.2	8.3	7.7	-
50% Solar	3,000	10.0	9.1	8.5	
60% Solar	4,875	12.4	11.5	10.8	-
Southern California					
(Los Angeles)					
50% Solar	1,500	6.7	6.1	5.6	-
60% Solar	2,175	7.8	7.2	6.7	-
70% Solar	3,000	9.0	8.3	7.7	-

[1]Electricity
[2]Oil

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Table 4.—The economics of solar space heating plus solar hot water heating vs. electric heat and hot water heat

Region	Solar system cost ($)	Pay out time years (electricity)			
		3¢/kWh	3½¢/kWh	4¢/kWh	5¢/kWh
East Coast - Boston					
40% Solar	4,875	10.2	9.1	8.2	-
50% Solar	6,750	10.9	9.8	8.9	-
East Coast - New York					
40% Solar	4,700	11.5	10.3	9.3	7.9
50% Solar	6,800	12.7	11.4	10.4	8.8
East Coast - Washington					
40% Solar	3,475	8.8	7.9	7.1	-
50% Solar	5,300	10.2	9.1	8.3	-
Upper Midwest (Omaha - Chicago)					
40% Solar	3,200	7.6	6.7	6.1	-
50% Solar	4,825	8.8	7.8	7.0	-
Lower Midwest (Nashville - St. Louis)					
40% Solar	3,275	9.5	8.5	7.6	-
50% Solar	4,825	10.7	9.6	8.6	-
Southwest (Dallas)					
40% Solar	2,200	8.2	7.3	6.6	-
50% Solar	3,000	8.7	7.8	7.0	-
60% Solar	4,875	10.9	9.8	7.8	-
Southern California (Los Angeles)					
50% Solar	1,500	5.7	5.0	4.5	-
60% Solar	2,175	6.7	5.9	5.3	-
70% Solar	3,000	7.6	6.7	6.0	-

Table 5.—The economics of solar space heating plus solar hot water heating vs. natural gas heat plus hot water heat

Region	Solar system cost ($)	Pay out time, years (gas)			
		12.5¢/therm	15¢/therm	17.5¢/therm	20¢/therm
East Coast - Boston					
40% Solar	4,875	20.5	18.9	17.6	16.5
50% Solar	6,750	21.5	19.8	18.5	17.3
East Coast - New York					
40% Solar	4,700	22.1	20.5	19.1	17.9
50% Solar	6,800	23.5	21.8	20.4	19.2
East Coast - Washington					
40% Solar	3,475	18.8	17.3	16.0	14.9
50% Solar	5,300	20.6	19.0	17.6	16.5
Upper Midwest (Omaha - Chicago)					
40% Solar	3,200	17.1	15.6	14.4	13.4
50% Solar	4,825	18.8	17.2	15.9	14.8
Lower Midwest (Nashville - St. Louis)					
40% Solar	3,275	19.7	18.1	16.8	15.7
50%	4,825	21.2	19.5	18.2	17.0
Southwest (Dallas)					
40% Solar	2,200	18.0	16.4	15.2	14.1
50% Solar	3,000	18.7	17.2	15.9	14.8
60% Solar	4,875	21.4	19.8	18.4	17.3
Southern California (Los Angeles)					
50% Solar	1,500	14.2	12.8	11.7	10.8
60% Solar	2,175	15.7	14.3	13.1	12.1
70% Solar	3,000	17.1	15.6	14.4	13.3

Table 6.—Heat values of fuels and electricity

Product	Btu	Unit
Anthracite	25,400,000	ton
Bituminous	26,200,000	ton
Coke	24,800,000	ton
Natural gas (Dry)	103,500	Cft[1]
Butane	102,000	gallon
Propane	91,500	gallon
Crude oil	5,800,000	barrel
Diesel fuel	138,238	gallon
Distillate fuel oil	138,690	gallon
Gasoline	125,071	gallon
Jet fuel	135,000	gallon
Kerosene	135,000	gallon
Electricity	3,412	kWh

Table 7.—Conversion factors

Product	Btu	Unit
Coal:		
Anthracite (Penn.)	25,400,000	Ton
Bituminous	26,200,000	Ton
Blast furnace gas	100	ft^3
Briquettes and package fuels	28,000,000	Ton
Coke	24,800,000	Ton
Coke breeze	20,000,000	Ton
Coke-oven gas	550	ft^3
Coal tar	150,000	gallon
Coke-oven and manufactured gas products, light oils	5,460,000	barrel
Natural gas (dry)	1,035	ft^3
Natural gas liquids (average)	4,011,000	barrel
Butane	4,284,000	barrel
Propane	3,843,000	barrel
Petroleum:		
Asphalt	6,640,000	barrel
Coke	6,024,000	barrel
Crude Oil	5,800,000	barrel
Diesel	5,806,000	barrel
Distillate fuel oil	5,825,000	barrel
Gasoline, aviation	5,048,000	barrel
Gasoline, motor fuel	5,253,000	barrel
Jet fuel:		
Commercial	5,670,000	barrel
Military	5,355,000	barrel
Kerosene	5,670,000	barrel
Lubricants	6,060,000	barrel
Miscellaneous oils	5,588,000	barrel
Refinery still gas	5,600,000	barrel
Heavy fuel oil	6,287,000	barrel
Road oils	6,640,000	barrel
Wax	5,570,000	barrel
Electricity	3,412	kWh

DOLLAR SAVINGS AND PAYOFF PERIOD FOR HEATING INSTALLATION* 2,000 SQ. FT. HOME – ELECTRIC HEAT

ENERGY COSTS	AVERAGE YEARLY EFFICIENCY OF SYSTEM	$ SAVED PER COLLECTOR PER YEAR	% YEARLY RETURN	PAYBACK PERIOD (YEARS) (100% OF INSTALLED COST CHARGED AGAINST SAVINGS)	ADJUSTED PAYBACK PERIOD (YEARS) (33% VALUE OF SYSTEM ADDED TO STRUCTURE)
LOW SOLAR RADIATION					
$.03/kW	60	35.00	11.2	9.0	5.9
	50	29.07	9.3	10.7	7.1
	40	23.19	7.4	13.8	9.0
$.05/kW	60	58.00	18.6	5.3	3.6
	50	48.20	16.4	6.0	4.0
	40	38.60	12.3	8.2	5.4
MEDIUM SOLAR RADIATION					
$.03/kW	60	46.20	14.8	6.7	4.5
	50	38.70	12.4	8.1	5.4
	40	30.86	9.9	10.3	6.5
$.05/kW	60	77.10	24.7	4.0	2.7
	50	64.50	20.7	4.8	3.2
	40	51.80	16.6	6.0	4.0
HIGH SOLAR RADIATION					
$.03/kW	60	58.00	18.6	5.3	3.6
	50	48.30	15.5	6.4	3.1
	40	38.60	12.4	8.1	3.6
$.05/kW	60	97.00	31.1	3.0	2.1
	50	80.80	26.1	4.0	2.6
	40	64.80	20.7	4.8	3.2

*At total installed system cost of $16.00/sq. ft.

DOLLAR SAVINGS AND PAYOFF PERIOD FOR HEATING INSTALLATION* 2,000 SQ. FT. HOME – OIL HEAT

ENERGY COSTS	AVERAGE YEARLY EFFICIENCY OF SYSTEM	$ SAVED PER COLLECTOR PER YEAR	% YEARLY RETURN	PAYBACK PERIOD (YEARS) (100% OF INSTALLED COST CHARGED AGAINST SAVINGS)	ADJUSTED PAYBACK PERIOD (YEARS) (33% VALUE OF SYSTEM ADDED TO STRUCTURE)
LOW SOLAR RADIATION					
$.40/Gal.	60	17.37	5.6	17.9	11.7
	50	14.56	4.7	21.3	14.1
	40	11.60	3.8	26.3	13.8
$.55/Gal.	60	23.94	7.2	13.9	8.7
	50	19.90	6.4	15.6	10.4
	40	15.90	5.1	19.6	13.0
$.70/Gal.	60	30.39	9.8	10.2	6.8
	50	25.40	8.2	12.2	8.1
	40	20.20	6.5	15.4	10.2
MEDIUM SOLAR RADIATION					
$.40/Gal.	60	23.15	7.4	13.5	8.8
	50	19.40	6.2	16.0	10.7
	40	15.50	5.0	20.0	13.3
$.55/Gal.	60	31.95	10.3	9.7	6.6
	50	26.50	8.5	11.8	7.9
	40	21.20	6.8	14.7	9.8
$.70/Gal.	60	40.55	13.0	7.7	5.1
	50	33.80	10.8	9.3	6.1
	40	27.10	8.7	11.5	7.6
HIGH SOLAR RADIATION					
$.40/Gal.	60	29.10	9.3	12.3	7.2
	50	24.20	7.8	14.6	8.5
	40	19.30	6.2	18.5	10.7
$.55/Gal.	60	39.90	12.7	9.0	9.4
	50	33.30	10.7	10.7	6.3
	40	26.60	8.5	13.4	7.8
$.70/Gal.	60	50.80	16.2	7.0	4.1
	50	42.30	13.6	8.4	4.9
	40	33.80	10.8	10.6	6.2

*At total installed system cost of $16.00/sq. ft.

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DOLLAR SAVINGS AND PAYOFF PERIOD FOR HEATING INSTALLATION* 2,000 SQ. FT. HOME – GAS HEAT

ENERGY COSTS	AVERAGE YEARLY EFFICIENCY OF SYSTEM	$ SAVED PER COLLECTOR PER YEAR	% YEARLY RETURN	PAYBACK PERIOD (YEARS) (100% OF INSTALLED COST CHARGED AGAINST SAVINGS)	ADJUSTED PAYBACK PERIOD (YEARS) (33% VALUE OF SYSTEM ADDED TO STRUCTURE)
LOW SOLAR RADIATION					
$.18/CCF	60	9.80	3.2	31.2	20.8
	50	8.17	2.6	38.5	25.6
	40	6.54	2.1	47.6	31.2
$.34/CCF	60	18.45	5.9	17.0	11.2
	50	15.35	5.0	20.0	13.3
	40	12.30	4.0	25.0	16.7
$.45/CCF	60	24.50	7.8	12.8	8.5
	50	20.40	5.5	18.2	12.5
	40	16.33	4.2	23.8	15.9
MEDIUM SOLAR RADIATION					
$.18/CCF	60	13.10	4.2	23.8	15.8
	50	10.90	3.5	28.5	18.8
	40	8.70	2.8	35.7	23.8
$.34/CCF	60	24.70	7.9	12.6	8.4
	50	20.60	6.6	15.1	10.0
	40	16.40	5.3	18.8	12.6
$.45/CCF	60	32.70	10.5	9.5	6.4
	50	22.70	7.3	13.7	9.2
	40	17.60	5.6	17.8	11.9
HIGH SOLAR RADIATION					
$.18/CCF	60	16.25	5.2	19.2	12.8
	50	13.50	4.4	22.7	15.1
	40	10.90	3.5	28.6	18.9
$.34/CCF	60	30.70	9.9	10.0	6.7
	50	25.60	8.2	12.2	8.1
	40	20.40	6.6	15.2	10.1
$.45/CCF	60	40.70	13.1	7.6	5.1
	50	28.20	9.1	11.0	7.3
	40	21.80	7.0	14.3	9.5

*At total installed system cost of $16.00/sq. ft.

May 30, 1975

Dear

The evaluation of your home's solar heating and energy conservation potential is complete and a synopsis of the results is given below. A detailed analysis is enclosed in the work sheets attached to this letter. In our analysis, the projected cost of electrical energy was used to determine how much solar energy and improved insulation would save you over a fifteen-year period. This cost savings was used to select an optimum system for you. However, projecting energy costs is risky because the effects of oil embargoes or of the President placing taxes on oil cannot be accurately determined. The projection data that we use was taken from a government report and probably underestimates future energy costs. Therefore, (company) expects you to save more than the amount we have stated in this evaluation.

The following is a synopsis of the evaluation results:

1. Your present home requires 38,500 Btu/degree day* for home heating and domestic hot water. This presently costs you $1200 per year. In fifteen years, based on projected energy costs, you would spend $2200 per year for the same. Accumulating all the yearly costs ofer a fifteen-year period, you would spend $26,257 to heat your home and hot water.

2. Your home insulation can be improved which will lower your annual heating bill. (Company) recommends the addition of storm windows and doors, insulating the hot air ducts and adding an additional three inches of insulation in the ceiling. Although you presently have thermopane windows and doors, storm doors and windows would reduce infiltration losses. These insulation improvements would lower your heating load by 21% and save you $251 per year at present energy costs. Using projected energy costs, over the course of fifteen years, these insulation improvements would save you $5492.08.

3. An operational schematic of the solar heating system is attached. It uses water as the heat transfer media and will provide domestic hot water as well as home heat. In the summer, excess solar heat not needed to heat the domestic water could be used to heat the swimming pool.

4. Two solar heating system sizes were optimal. The solar heating system (company) recommends would have a solar collector area of 500 square feet, and would be mounted on modules in your backyard. Since your home faces 41 degrees away from south, solar collector placement on your roof was unadvisable. A diagram of this system, shown with the proposed swimming pool, is also attached. (Company) recommends this solar heating system be considered only in conjunction with the improved insulation package.

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*A degree-day is an engineering measure of the amount of heat your home requires based on local weather data. A Btu is a unit of heat.

5. The other solar heating system optimized has an area of 800 square feet. However, since a larger system is more costly, and the recommended system is mounted on modules, additional collector area could be added to the recommended system at a later date.

6. The recommended 500 square feet system would supply 35% of the yearly heating load of the recommended better insulated home. This system (recommended system No. 3 of the work sheets) would, in combination with the insulation package, save you $608 per year, or over half of what you are presently paying. Usine projected energy costs, this solar heat and insulation package would save you $13,288 over the course of fifteen years.

7. The solar heating system is estimated to cost $20 per square foot yielding a cost of $10,000. The insulation improvements are estimated to cost $2,000. The total package cost is estimated to be $12,000, and should pay for itself in about thirteen years. A firm fixed price for the package would be quoted when a solar heating installation contract is negotiated. If you install the system yourself, (company) supplying plans, technical advice and materials, the solar heating system cost could be reduced to $6,500.

8. The excess solar heat obtained in the summer months can be used to heat your pool at a savings of $290 per summer at present energy costs. Using projected energy costs, over the course of fifteen years, the excess solar heat would save you an additional $6,300. This excess solar heat, in combination with a pool cover, which (company) recommends, would raise the pool water temperature 7 degrees over that of an unheated, uncovered pool.

The following table lists our recommendations, their costs, and your expected savings.

RECOMMENDATION	ESTIMATED COST	PROJECTED SAVINGS OVER FIFTEEN YEARS
Insulation Package	$ 2,000	$ 5,492
500-square-foot solar heating	10,000	13,288 (includes insulation)
Solar pool heat	—0—	6,300
Total	12,000	19,588

If you have any questions about this evaluation, please feel free to contact us.

Sincerely,

Enclosures: (1) Work Sheets
(2) Operational Schematic
(3) Collector Array Diagram
(4) Solar Profile

Solar Heating Potential Survey

DATE: May 30, 1975

NAME:

ADDRESS:

SURVEYORS (S):

SURVEY INFORMATION ATTACHED: yes

PRESENT HEATING LOADS AND REQUIREMENTS

DOMESTIC HOT WATER	LOAD	PRESENT ESTIMATED COST
MINIMUM	440 kWh/mo	$15.00/mo
MAXIMUM	880 kWh/mo	30.00/mo

PRESENT HOME HEATING REQUIREMENTS:

HEATING BILLS: Analysis of your home heating bills in conjunction with local weather data yields a home heating load of 38,500 Btu/degree-day.

CONSTRUCTION DETAILS (Drawings available):

ITEM	AREA (ft^2)	NOTES
CEILING	2,718	6" insulation
CEILING (other)	0	
WALLS (exposed to dirt)	200	block
WALLS (exposed to air)	1,936	3.62" insulation
WALLS (to unheated space)	0	
WALLS (other)	435	block to air
WINDOWS AND S.G. DOORS	400	thermopane
WINDOWS (other)	13	skylight
FLOOR (crawl space)	560	6" insulation
FLOOR (unheated space)	644	
FLOOR (dirt)	2,592	
FLOOR (other)	0	
ADDITIONAL	0	

Analysis of your home construction details yields a home heating load of 39,950 Btu/degree-day.

HOME HEATING LOAD USED IN THIS EVALUATION: 38,500 Btu/degree-day

ESTIMATED YEARLY HEATING LOAD, INCLUDING HOME HEAT AND DOMESTIC HOT WATER

	Btu/year	kWh/year	Present Cost
52	211×10^6	61.8×10^3	$1,200.00

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PRESENT COST OF HEATING ENERGY: $0.02/kWh

INSULATION EVALUATION

WINDOWS: Add storm windows to reduce infiltration losses

SAVINGS: Reduce heat load by 6 percent

COST:

DOORS: Add storm doors to reduce infiltration losses

SAVINGS: Reduce heat losses by 7 percent

COST:

FLOORS: None

SAVINGS:

COST:

CEILING: Increase insulation thickness from 6 inches to 9 inches

SAVINGS: Reduce heat load by 2 percent

COST:

WALLS: None

SAVINGS:

COST:

OTHER: Insulate exposed air ducts with 3.5 inches insulation

SAVINGS: 10 percent

COST:

INSULATION IMPROVEMENT EFFECT ON PRESENT YEARLY HEATING LOAD

PRESENT HEAT LOAD	IMPROVED HEAT LOAD	IMPROVED HEATING COST	YEARLY SAVINGS USING PRESENT ENERGY COSTS
61,800 kWh/yr	47,400 kWh/yr	$949.00/yr	$251.00/yr

TOTAL COST OF INSULATION IMPROVEMENT RECOMMENDATIONS:

SOLAR HEATING SYSTEM APPLIED TO YOUR HOME

LOCATION OF THE SOLAR COLLECTOR ARRAY:	The best and easiest to install location for the solar collectors would be in the backyard. A diagram of this array, shown together with the proposed swimming pool is included in this evaluation.
LOCATION OF THE STORAGE TANK:	The heat storage tank would best be located inside the structure which holds the solar collector array.
OTHER CONSIDERATIONS:	This evaluation will also consider the solar heating impact on a proposed swimming pool.

Solar Heating System

RECOMMENDED SYSTEM #1

COLLECTOR AREA: 800 square feet LOCATION: Backyard

ORIENTATION: See diagram TILT ANGLE: 55 degrees

STORAGE TANK SIZE: 1200 gallons

STORAGE TANK LOCATION: Backyard

System Performance Details

MONTH	PRESENT HOME HEAT LOAD/MO (Million Btu)	HEAT SUPPLIED BY RECOMMENDED SOLAR HEATING SYSTEM (Million Btu/mo)	PERCENT SOLAR HEAT	EXCESS HEAT (FOR POOL) (Million Btu/mo)
JAN	40.8	8.2	20	-
FEB	35.0	9.0	25.7	-
MAR	29.2	11.5	39.3	-
APR	15.2	12.3	80.9	-
MAY	6.6	6.6	100	7.7
JUN	1.7	1.7	100	13.6
JUL	1.6	1.6	100	15.1
AUG	1.6	1.6	100	16.3
SEP	3.2	3.2	100	13.0
OCT	12.8	12.8	100	2.8
NOV	24.9	10.6	42.5	-
DEC	38.5	7.7	20	-
TOTAL	211.1	86.8		

PRESENT YEARLY HEATING BILL SAVINGS FOR ABOVE SYSTEM USING PRESENT ENERGY COSTS: $488.00

PROJECTED YEARLY HEATING COSTS WITH AND WITHOUT SOLAR HEAT

TIME	PRESENT HOME HEATING COSTS NO SOLAR HEAT $/YR	PRESENT HOME HEATING COSTS W/SOLAR HEAT $/YR	PROJECTED YEARLY SAVINGS
PRESENT	1,200	712	488
IN 5 YEARS	1,532	910	622
IN 10 YEARS	1,866	1,108	758
IN 15 YEARS	2,198	1,305	893
ACCUMULATED COSTS AND SAVINGS	26,257	15,596	10,668

ESTIMATED* COST OF INSTALLING SOLAR HEATING SYSTEM: $20.00/ft² = $16,000.00

NOTE: This system would take about 20 years to pay for itself.

* The cost of solar heating system is only an estimate used in this evaluation. Although the estimate should not change by much a firm fixed price would be quoted when a solar heating installation contract is negotiated.

RECOMMENDED SYSTEM #2

COLLECTOR AREA: 800 square feet LOCATION: Backyard

ORIENTATION: see diagram TILT ANGLE: 55 degrees

STORAGE TANK SIZE: 1200 gallons

STORAGE TANK LOCATION: Backyard

OTHER CONSIDERATIONS: Assume home to be insulated to above recommendations. Home heating load reduced to 47,400 kWh/yr.

PERCENT OF YEARLY HEATING BILL SUPPLIED BY ABOVE SOLAR HEATING SYSTEM: 52.7 percent for insulated home above, based on 47,400 kWh/yr usage.

PROJECTED YEARLY HEATING COSTS FOR UPGRADED INSULATION HOME WITH AN 800-SQUARE FOOT SOLAR HEATING SYSTEM

Time	Present home, present insulation no solar $/yr	Insulated home with solar heat $/yr	Projected yearly savings $/yr
Present	1,200	448	752
In 5 years	1,532	549	983
In 10 years	1,866	696	1,170
In 15 years	2,198	820	1,378
Accumulated costs and savings in 15 years	26,257	9,516	16,731

ESTIMATED* COST OF INSTALLING SOLAR HEATING SYSTEM: $20/ft² plus $2,000 for insulation = $18,000

NOTE: This system would pay for itself in about 16 years.

*The cost of solar heating system is only an estimate used in this evaluation. Although the estimate should not change by much, a firm fixed price would be quoted when a solar heating installation contract is negotiated.

RECOMMENDED SYSTEM #3

COLLECTOR AREA: 500 square feet LOCATION: Backyard

ORIENTATION: See diagram TILT ANGLE: 55 degrees

STORAGE TANK SIZE: 750 gallons

STORAGE TANK LOCATION: Backyard

OTHER CONSIDERATIONS: Consider home to be insulated to recommendations. Home heating load estimated to be reduced to 47,400 kWh/yr.

PERCENT OF YEARLY HEATING BILL SUPPLIED BY ABOVE SOLAR HEATING SYSTEM: 35.6% of insulated home above, based on 47,400 kWh/yr usage.

PROJECTED YEARLY HEATING COSTS FOR UPGRADED INSULATION HOME WITH A 500 SQUARE FOOT SOLAR HEATING SYSTEM

Time	Present home present insulation, no solar $/yr	Insulated home with solar heat $/yr	Projected yearly savings $/yr
Present	1,200	610	590
In 5 years	1,532	748	784
In 10 years	1,866	949	917
In 15 years	2,198	1,117	1,081
Accumulated costs and savings	26,257	12,968	13,288

ESTIMATED* COSTS OF INSTALLING SOLAR HEATING SYSTEM: $20/ft² plus $2,000 for insulation improvements = $12,000

NOTE: This system would pay for itself in about 13 years.

*The cost of solar heating system is only an estimate used in this evaluation. Although the estimate should not change by much, a firm fixed price would be quoted when a solar heating installation contract is negotiated.

SOLAR HEATING SYSTEM FOR POOL

POOL SIZE: 40 ft by 20 ft by 5 ft (average)

POOL LOCATION: Backyard, between house and collector array

SOLAR COLLECTOR SIZE: 500 square feet

NOTES: Collector used for home heat. Excess in the summer time will be used to help heat pool. Heat input from standard pool heater was not considered.

POOL COVERING: A pool cover was considered. It would be in place 12 hours per day.

WATER TEMPERATURES IN POOL, DEGREES FAHRENHEIT

Month	No pool cover, no solar heat	No pool cover, solar heat	Pool cover solar heat	Pool cover no solar heat	Average air temp
May	63	64	68	67	66
Jun	70	72	77	74	74
Jul	73	75	81	77	79
Aug	70	73	78	74	77
Sep	64	66	71	67	70

TOTAL AMOUNT OF ENERGY SUPPLIED TO POOL DURING SUMMER MONTHS: 49.6 million Btu

TOTAL AMOUNT OF ENERGY SUPPLIED TO POOL DURING WINTER MONTHS: 0

ESTIMATED ENERGY COSTS FOR CONVENTIONAL POOL HEATER: $0.020/kWh summer
0.0 winter

ESTIMATED ENERGY SAVINGS PER YEAR USING SOLAR HEAT FOR POOL: $290.00

COMMENTS: Solar augmented pool heat with a pool cover used 12 hours per day would raise the pool water temperature by about 7 degrees as compared to an unheated, uncovered pool.

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July 17, 1975

Dear

An evaluation of the energy required for the home you plan to build is complete and a synopsis of the results is given below. A detailed analysis is enclosed in the work sheet attached. In our analysis, the projected cost of energy was used to determine how much solar energy and various wall construction would save you. However, projecting energy cost is risky because the effect of oil embargoes, taxes, and energy legislation cannot be accurately determined. The projection data that we used was taken from a government report and probably underestimates future energy costs. Therefore, [company] expects you to save more than the amount stated in this evaluation.

Sincerely

President,

Enclosures

SYNOPSIS OF EVALUATION RESULTS

The following is a synopsis of the evaluation results:

1. The calculated heating requirement of your home is 115.8 million Btu's per year using the heat loss data presented in the attached worksheet.

2. The walls were assumed to be ½-inch dry wall on 2-inch by 4-inch studs, with 3½" fiberglass insulation, with ½" plywood exterior sheathing finished with ¾-inch cedar boards with batting strips. We recommend that you do not have an air space under the ¾-inch cedar as this will save only .2 Btu/Ft²/Degree Day and will have to spend a large amount of time and money assuring that there is no infiltration losses. If you nail the ¾-inch cedar directly to the ½-inch sheathing and then nail on the batting strips, you will have a much stronger construction and minimize the effect of infiltration.

3. We have calculated the heat loss of the windows, doors, walls and ceilings for various types of construction. Considering the estimated cost of these various wall constructions, we recommend that you consider a wall constructed of 2- by 4-inch studs with ½-inch Polyurethane Foam (PF) and 3-inch Urea Foam (UF) sprayed on before the interior of your studs are closed up. This type of construction offers very effective thermal and acoustic insulation. The PF forms a vapor barrier and cuts infiltration losses. The UF is cheaper and protects the PF from fire.

4. The conduction and infiltration losses of the sliding glass doors is substantial, comprising 26 percent of your heat load. We recommend that you take a careful look at these losses. Our calculations were based on installation that was made using caulking, weather stripping and good construction techniques. If you do not make sure that these doors are of high quality and are installed properly, you can expect to realize infiltration losses as large as two times those calculated.

5. Shading is another important factor to consider. We estimate that the output from a solar heating system will be degrated 25 percent if you clear all trees, taller than your house, on the east, south, and west side of your house that are closer than 50 feet. If you clear these same trees that are within 95 feet, you will realize little shading effect. If you do not clear any trees, we would not recommend solar heat for your home.

6. The enclosed system performance data sheet compares five systems from 100 to 500 ft^2. The 100, 150, and 200 ft^2 systems provide heat only for domestic hot water. Systems of 300 ft^2 and larger provide heat for both domestic hot water and home heat. Interpretation of this data yields the following conclusions.

a. Solar home heat is not economically advantageous for your home as compared to oil heat. This is attributable to a combination of your shallow roof, the present relatively low cost of oil heat, and the present high cost of a solar collector.

b. A domestic solar hot water heater system could provide 55 to 79 percent of your hot water need and pay for itself in 10 years.

Present Heating Loads and Costs

Domestic hot water (electrically heated)	Load	Present estimated cost
2 persons	3662 kWh/yr	$148/yr*
4 persons	7325 kWh/yr	$297/yr*

*Based on cost of $.0405/kWh

Analysis of your home construction details yields a home heating load of:

23,139 Btu/degree day

This heat load, in conjunction with local weather, yields a home heating requirement of:

115.98 x 10^6 Btu/yr

Home heating	Load	Presented estimated cost
Electric @ $.0405/kWh	43,862 kWh/yr	$1,776/yr
Oil @ $.40/gal	115.98 x 10^6 Btu/yr	$332/yr

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Type construction	Heat loss Btu/ft²/deg day	Approximate cost $/ft²
Glass, Single	13.0	--
Glass, Double ¼" Space	9.1	--
Glass, Single + Storm Windows	9.9	--
Frame, 2" × 4" with 3½" Fiberglass	1.8	4*
Frame, 2" × 4" with 3½" Fiberglass + 1" Air	1.7	--
Frame, 2" × 4" with ½" PF + 3" UF	1.3	.8**
Frame, 2" × 4" with ½" PF + 3" UF + 1" Air	1.05	--
Frame, 2" × 6" with 5½" Fiberglass	1.13	.55*
Frame, 2" × 6" with ½" PF + 5" UF	.76	1.0**
Block, 8"	6.5	--
Block, 8" 1" Air + Interior	4.0	--
Block, 8" ¾" Styrofoam + Interior	3.6	--
Block, 8" 3½" Fiberglass	1.2	--
Block, 8" ½" PF + 3" UF	.92	--
Roofing, Shingles only	----	.4 (installed)
Roofing, 2" wood, 2½" PF + Shingles	1.14	1.95**
Roofing, 2½" PF only	----	1.00

*Cost of frame materials (interior and exterior materials not included).

**Same as above with insulation installed.

House Heating Load

Components	Area ft²	Pct of total area	Loss factor Btu/ft²/deg day	Loss Btu/deg day	Pct of total loss
Windows, Fixed	383	6.0	9.1	3,485	15.1
Windows, Sliding	45	.7	9.1	410	1.8
Infiltration windows	428	6.7	---	525	2.3
Doors, Swinging	28	.4	9.1	255	1.1
Infiltration doors, Swinging	28	.4	---	367	1.6
Doors, Sliding	306	4.8	9.1	2,785	12.0
Infiltration doors, Sliding	306	4.8	---	3,244	14.0
Ceiling	1,784	28.3	1.14	2,034	8.8
Wall 8" block	317	5.0	6.5	2,061	8.9
Wall to garage	272	4.3	4.36	1,186	5.1
Wall to fill	592	9.4	2.35	1,390	6.0
Wall frame	922	14.6	1.8	1,660	7.2
Floor to fill	1,389	22.0	2.34	3,250	14.0
Floor to garage	264	4.2	1.89	500	2.2

Projected Heating Costs

TIME	ELECTRIC - HOT WATER OIL - HOME HEATING		TOTAL ELECTRIC	
	Rate increase of 5.55 pct/yr	7 pct/yr	5.55 pct/yr	7 pct/yr
	TOTAL COST			
Present	$ 630/yr	$ 630/yr	$2,073/yr	$2,073/yr
In 5 yrs	806.4/yr	850.5/yr	2,080/yr	2,199/yr
In 10 yrs	1,008/yr	1,071/yr	2,533/yr	2,769/yr
In 15 yrs	1,160/yr	1,292/yr	2,984/yr	3,280/yr
	ACCUMULATED COSTS			
In 5 yrs	3,567/yr	3,701/yr	9,273/yr	9,568/yr
In 10 yrs	8,063/yr	8,506/yr	20,805/yr	21,986/yr
In 15 yrs	13,292/yr	14,412/yr	34,590/yr	37,253/yr

Monthly Heating Requirements and Available Solar Energy

Month and no. degree days	Home heat load/mo (million Btu)	Hot water load/mo (million Btu)	Total load/mo (million Btu)	Available solar energy/mo Btu/ft²
Jan. 1,020	23.60	2.07	25.67	6,448
Feb. 874	20.25	2.07	22.32	7,812
Mar. 719	16.64	2.07	18.71	11,191
Apr. 357	8.27	2.07	10.34	12,480
May 131	3.03	2.07	5.10	14,446
Jun. 5	.12	2.07	2.19	15,150
Jul. 0	---	2.07	2.07	15,779
Aug. 0	---	2.07	2.07	14,973
Sep. 43	1.00	2.07	3.07	12,990
Oct. 291	7.72	2.07	9.80	11,222
Nov. 609	14.10	2.07	16.17	7,950
Dec. 961	22.24	2.07	24.31	6,293

Solar Domestic Hot Water Heating System

Recommended system

Collector area: 100
Orientation: S 15° W
Storage tank size: 250
Storage tank location: Basement

Location: Roof
Tilt angle: 18°

System Performance Details

Month	Hot water heating load/mo (million Btu)	Heat supplied by recommended solar system (million Btu/mo)	Percent solar heat
Jan.	2.07	.65	31
Feb.	2.07	.78	38
Mar.	2.07	1.12	54
Apr.	2.07	1.25	60
May	2.07	1.44	70
Jun.	2.07	1.52	73
Jul.	2.07	1.58	76
Aug.	2.07	1.50	72
Sep.	2.07	1.30	63
Oct.	2.07	1.12	54
Nov.	2.07	.8	39
Dec.	2.07	.63	30
Total	24.84	13.69	

Present yearly heating bill savings for above system using present energy costs: $163

Projected Yearly Heating Costs with and Without Solar Heat

Time	Present heating costs no solar heat $/yr	Present heating costs w/solar heat $/yr	Accumulated savings
Present	297	134	163
In 5 yrs	380	171	928
In 10 yrs	475	214	2,082
In 15 yrs	547	246	3,462

Estimated* cost of installing solar heating system @ $20/ft² = $2,000

* The cost of solar heating system is only an estimate used in this evaluation. Although the estimate should not change by much, a firm fixed price would be quoted when a solar heating installation contract is negotiated.

NOTE: This system would take about 10 years to pay for itself.

System Performance Data

System size ft²	Energy provided (million Btu/pct	Present cost $.04/kWh	Savings first yr	Estimated accumulated savings @ 5.55 pct In 5 yrs	In 10 yrs	In 15 yrs	Est system cost	Years for savings to pay for system
100								
Hot water	13.7	$297	160	$912	$2,045	$3,398	$2,000	10
Heat	--							
Total	13.7							
	55%							
150								
Hot water	19.74	297	231	1,317	2,952	4,906	3,000	10
Heat	---							
Total	19.74							
	79%							
200								
Hot water	22.26	297	261	1,487	3,341	5,544	4,000	12
Heat	---							
Total	22.26							
	89%							
300								
Hot water	24.60	297	297	1,603	3,745	6,223	6,000	14
Heat	7.63	303	19.6	112	251	417		
Total	32.63	600	312.6	1,715	3,996	6,640		
	25%							
500								
Hot water	25.0	297	297	1,693	3,796	6,308	10,000	20
Heat	20.81	303	54	307	690	1,147		
Total	45.81	600	347	1,910	4,486	7,455		
	35%							

Silver Spring, MD 20904

Dear Mr. A

The evaluation of your home's solar heating and energy conservation potential is complete and a synopsis of the results is given below. Detailed analyses are enclosed in the work sheets attached to this letter. [Company] has also included the effect of a heat pump on your yearly heating costs in addition to our normal analysis of a solar heating system for your home. In all of our analyses the projected cost of electrical energy was used to determine how much solar energy heating systems (or heat pump systems) would save you over a fifteen year period. This cost savings was used in selecting an optimum system for you. However, projecting energy costs is risky because the effects of oil embargoes or Presidential taxes cannot be accurately determined. The projection data that we used was taken from government reports and probably underestimates future energy costs. [Company] expects you to save more than the amount we have stated in this evaluation. Throughout this report, we have used an energy cost inflation rate of 7%.

Heating system capital recovery costs were not included in this evaluation. Since loan interest rates and periods vary, an accurate determination of investment money cost cannot be made. However, it is important to note that money costs will affect the systems payback period (the period of time after which the system operates for essentially free). There is sufficient data within this evaluation to allow you to determine the effect of money costs for your own situation.

The following is a synopsis of the evaluation results:

1. HEATING REQUIREMENTS—
   Your home requires 22.636 kwhr/yr for space heating and 5,110 kwhr/yr for domestic hot water heating. During the present year, these two items will cost you $903. In fifteen years, based on projected energy costs, you will spend $2,327 for the same energy. Accumulating all the yearly costs over a fifteen year period, you would spend $26,257 to heat your home and hot water.
2. INSULATION EVALUATION—
   The insulation in your home is outstanding. However, if you should ever finish and heat your basement, [company] recommends the basement block wall be insulated. One type of insulation material could be ¾-inch thick styrofoam boards that fit behind paneling. Since your basement is presently unheated and unfinished, the minor effect of basement insulation on your present heating requirements was not included in this evaluation.
3. ENERGY CONSERVATION IMPROVEMENTS (HEAT PUMP)—
   The effect of an electric heat pump on your yearly heating bill was considered. A heat pump can reduce your space heating requirements (not hot water requirements) by approximately 30% in the Washington, D.C. area. This would reduce the yearly total heating bill from $903 to $685 per year for a yearly savings of $218. Using projected energy costs, a heat pump would save your $5,475 over the course of fifteen years. An installed heat pump is estimated to cost $2,500 and would require 8¾ years to pay back its initial cost. We obtained unfavorable impressions about heat pumps from two local refrigeration/air-conditioning contractors. Their two main complaints were low reliability and high maintenance. However, it is possible that recent heat pump improvements have dimished these problems.

   Hybrid heat pumpm/solar collector systems have also been proposed, and promise excellent efficiency. However, data on this system's performance is unavailable, and [company] did not estimate its effect on your heating bill. We do not recommend the hybrid system at this time.
4. SOLAR HEATING SYSTEMS—
   Two solar heating systems were optimized for your home. One would heat both your home and domestic hot water and the other would heat only your domestic hot water. Both systems would use a solar collector mounted on your south facing roof and store energy in a heat storage tank located in your basement.

A. SOLAR SPACE HEATING SYSTEM — For solar heating of your home and domestic hot water, [company] recommends a solar heating system with a collector area of 400 square feet and a storage tank size of 800 gallons. This system would supply 45% of the yearly heating energy needs for your home. It would reduce your present heating energy costs from $903 to $496 and save you $407 per year. Based on projected energy costs, this system would save you $10,224 over the course of fifteen years. This system is estimated to cost $8,000 and would require 12¾ years to pay for itself.

B. SOLAR DOMESTIC HOT WATER HEATING SYSTEM — The second solar heating system considered for your home would heat only your domestic hot water. For this system, [company] recommends a solar collector with an area of 100 square feet and a storage tank size of 150 gallons. This system would supply 85% of your estimated domestic hot water needs. Your average hot water requirements were estimated to be 100 gallons per day. Since you presently spend approximately $177 per year to heat domestic hot water, this system would presently save you $150 per year. In fifteen years, this system would save you $389 per year. Using projected energy costs, this system would save you $3,793 over the course of fifteen years. A solar heated domestic hot water system is estimated to cost $2,000 and would require 9¾ years to pay for itself. This system would be designed so that it could be expanded into System "A" at a future date if desired.

5. SOLAR HEATED POOL DATA—
Excess solar heat obtained in the summer months from the solar space heating system (400 square feet of collector area) could be used to heat your pool. This excess solar heat, in combination with a pool cover, which [company] recommends for higher pool temperatures, would raise the pool water temperature 6 degrees over that of an unheated, uncovered pool. This would presently save you $223 per year at present energy costs. Over the course of fifteen years, this solar pool heater would save you $5,600.

Both a heat pump and a solar heated domestic hot water system could be added to your home. These are separate systems, not the hybrid systems mentioned in 3 above. In combination, these two systems would presently save you $368 per year. Over a fifteen year period, using projected energy costs, they would save you a total of $9,268.

In summary, [company] recommends a preliminary installation of a solar heated domestic hot water system. It is less expensive than the solar space heating system and could easily be expanded into a space heating system if desired. It would be less expensive to expand an existing solar domestic hot water heating system than to initially install a solar space heating system. Part of the domestic hot water system, plumbing, controls, etc., also needed for the space heating system would already exist. The relatively inexpensive solar heated domestic hot water system would give you complete exposure to the potential of solar energy and would allow you the flexibility of installing a heat pump without wasted capital.

Solar Heating Potential Survey

DATE: 8 July 1975

NAME:
ADDRESS:

SURVEYOR(S):
SURVEY INFORMATION ATTACHED: No

PRESENT HEATING LOADS AND REQUIREMENTS

DOMESTIC HOT WATER:	LOAD	PRESENT ESTIMATED COST
MIN	366 kWh/mo	$149/yr
MAX	502 kWh/mo	$205/yr
	Avg = 434 kWh/mo	Avg = $177/yr

PRESENT HOME HEATING REQUIREMENTS:

HEATING BILLS: Analysis of your home heating bills in conjunction with local weather data yields a home heating load of:
Space heating = 22,636 kWh/yr
Domestic Hot Water = 5,110 kWh/yr

CONSTRUCTION DETAILS

ITEM	AREA (ft^2)	NOTES
CEILING		
CEILING (OTHER)		
WALLS (EXPOSED TO DIRT)		
WALLS (EXPOSED TO AIR)		
WALLS (TO UNHEATED SPACE)		
WALLS (OTHER)		
WINDOWS AND S. G. Doors		*Not applicable*
WINDOWS (OTHER)		
FLOOR (CRAWL SPACE)		
FLOOR (UNHEATED SPACE)		
FLOOR (DIRT)		
FLOOR (OTHER)		
ADDITIONAL		

Analysis of your home construction details yields a home heating load of:

Not applicable

HOME HEATING LOAD USED IN THIS EVALUATION: 22,636 kWh/yr

ESTIMATED YEARLY HEATING LOAD, INCLUDING HOME HEAT AND DOMESTIC HOT WATER

Btu/yr	kWh/yr	PRESENT COST
94.7×10^6	27,746	$903

PRESENT COST OF HEATING ENERGY: $0.0325/kWh

INSULATION EVALUATION

WINDOWS:	Not Applicable	CEILING:	Not Applicable
DOORS:	Not Applicable	WALLS:	Not Applicable
FLOORS:	Not Applicable	OTHER:	Not Applicable

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INSULATION IMPROVEMENT EFFECT ON PRESENT YEARLY HEATING LOAD

PRESENT HEAT LOAD	IMPROVED HEAT LOAD	IMPROVED HEATING COST	YEARLY SAVINGS USING PRESENT ENERGY COSTS
22,636 kWh/yr	N/A	N/A	N/A

TOTAL COST OF INSULATION IMPROVEMENT RECOMMENDATIONS: N/A

SOLAR HEATING SYSTEM APPLIED TO YOUR HOME

LOCATION OF THE SOLAR COLLECTOR ARRAY:

The best collector location would be on the south facing part of your roof. Although the shallow pitch of your roof degrades system performance slightly, it is less expensive to install more collector area than to change collector tilt angle.

LOCATION OF THE STORAGE TANK:

Basement of home.

OTHER CONSIDERATIONS:

Consider the impact of solar heating on the swimming pool water temperatures.

RECOMMENDED SYSTEM: Electric Heat Pump

COLLECTOR AREA: N/A
ORIENTATION: N/A
STORAGE TANK SIZE: N/A
STORAGE TANK LOCATION: N/A
OTHER CONSIDERATIONS: N/A
LOCATION: N/A
TILT ANGLE: N/A

PERCENT OF YEARLY HEATING BILL SUPPLIED BY ABOVE HEAT PUMP SYSTEM: 30 percent

Projected Yearly Heating Costs for Heat Pump Heating System

Time	Present home present insulation no solar $/yr	Insulated home with heat pump $/yr	Projected yearly savings $/yr
Present	903	685	218
In 5 yrs	1,182	897	285
In 10 yrs	1,659	1,259	400
In 15 yrs	2,327	1,765	562
Accumulated costs and savings in 15 yrs	22,683	17,207	5,476

ESTIMATED* COST OF INSTALLING ELECTRIC HEAT PUMP SYSTEM: $2500

NOTE: This system would pay for itself in about 8.75 years

* The cost of solar heating system is only an estimate used in this evaluation. Although the estimate should not change by much, a firm fixed price would be quoted when a solar heating installation contract is negotiated.

Solar Heating System

RECOMMENDED SYSTEM

COLLECTOR AREA: 400 Square feet
ORIENTATION: Due South
STORAGE TANK SIZE: 800 gallons
STORAGE TANK LOCATION: Basement
OTHER CONSIDERATIONS: Excess solar heat to swimming pool
LOCATION: Roof
TILT ANGLE: 26°

System Performance Details

Month	Present home heat load/mo (million Btu)	Heat supplied by recommended solar heating system (million Btu/mo)	Percent solar heat	Excess heat (for pool) (million Btu/mo)
Jan.	17.2	3.4	20	---
Feb.	14.8	4.1	28	---
Mar.	12.6	5.7	45	---
Apr.	6.9	6.2	90	0
May	4.6	4.6	100	2.6
Jun.	1.5	1.5	100	5.7
Jul.	1.5	1.5	100	5.9
Aug.	1.5	1.5	100	5.6
Sep.	2.1	2.1	100	4.3
Oct.	4.9	4.9	100	.7
Nov.	10.8	4.1	38	0
Dec.	16.3	3.1	20	---
Total	94.7	42.7	45%	24.8

PRESENT YEARLY HEATING BILL SAVINGS FOR ABOVE SYSTEM USING PRESENT ENERGY COSTS: $903/yr

Projected Yearly Heating Costs With and Without Solar Heat

Time	Present home heating costs no solar heat $/yr	Present home heating costs w/solar heat $/yr	Projected yearly savings
Present	903	496	407
In 5 yrs	1,182	649	533
In 10 yrs	1,659	911	748
In 15 yrs	2,327	1,278	1,049
Accumulated costs and savings	22,683	12,459	10,224

ESTIMATED* COST OF INSTALLING SOLAR HEATING SYSTEM: $20.00/ft² = $8000

NOTE: This system would take about 12.75 years to pay for itself.

* The cost of solar heating system is only an estimate used in this evaluation. Although the estimate should not change by much, a firm fixed price would be quoted when a solar heating installation contract is negotiated.

Solar Heating System

RECOMMENDED SYSTEM: Domestic Hot Water
COLLECTOR AREA: 100 Square Feet
ORIENTATION: Due South
STORAGE TANK SIZE: 150 gallons
STORAGE TANK LOCATION: Basement
LOCATION: Roof
TILT ANGLE: 26°

System Performance Details—Domestic Hot Water

Month	Present home heat load/mo (million Btu)	Heat supplied by recommended solar heating system (million Btu/mo)	Percent solar heat	Excess heat (for pool) (million Btu/mo)
Jan.	1.48	0.89	60	
Feb.	1.34	1.04	77	
Mar.	1.48	1.48	100	
Apr.	1.43	1.43	100	
May	1.48	1.48	100	N/A
Jun.	1.43	1.43	100	
Jul.	1.48	1.48	100	
Aug.	1.48	1.48	100	
Sep.	1.43	1.43	100	
Oct.	1.48	1.39	93	
Nov.	1.43	1.05	73	
Dec.	1.48	0.76	51	
Total	17.42	15.32	85	

PRESENT YEARLY HEATING BILL SAVINGS FOR ABOVE SYSTEM USING PRESENT ENERGY COSTS: $150/yr. 17 percent reduction in present heating costs.

Projected Yearly Heating Costs With and Without Solar Heat

Time	Present water heating costs no solar heat $/yr	Present water heating costs w/solar heat $/yr	Projected yearly savings
Present	177	27	150
In 5 yrs	232	36	196
In 10 yrs	325	47	278
In 15 yrs	456	67	389
Accumulated costs and savings	4,446	653	3,793

ESTIMATED* COST OF INSTALLING SOLAR HEATING SYSTEM: $20.00/ft² = $2000

NOTE: This system would take about 9.75 years to pay for itself.

* The cost of solar heating system is only an estimate used in this evaluation. Although the estimate should not change by much, a firm fixed price would be quoted when a solar heating installation contract is negotiated.

Solar Heating System for Pool

POOL SIZE: 730 Square feet area, 26,000 gallons
POOL LOCATION: Backyard, in view of sun
SOLAR COLLECTOR SIZE: 400 square feet
NOTES: Collector used for home heat. Excess in the summer time will be used to help heat pool. Heat input from a standard pool heater was not considered.
POOL COVERING: A pool cover was considered. It would be in place 12 hrs per day.

WATER TEMPERATURES IN POOL, DEGREES FAHRENHEIT

Month	No pool cover, no solar heat	No pool cover, solar heat	Pool cover solar heat	Pool cover no solar heat	Average air temp
May	65.4	66.8	71.8	69.9	66
Jun.	72	74.8	81.4	78	74
Jul.	75.3	77.7	83.2	81	79
Aug.	72.7	75.3	81.1	77.7	77
Sep.	66.3	69.1	72.5	70.2	70

TOTAL AMOUNT OF ENERGY SUPPLIED TO POOL DURING SUMMER MONTHS: 24.8 x 10^6 Btu

TOTAL AMOUNT OF ENERGY SUPPLIED TO POOL DURING WINTER MONTHS: None

ESTIMATED ENERGY COSTS FOR CONVENTIONAL POOL HEATER: Bottled Gas = $9.00/million Btu

ESTIMATED ENERGY SAVINGS PER YEAR USING SOLAR HEAT FOR POOL: $223

COMMENTS: Solar augmented pool heat with a pool cover used 12 hours per day would raise the pool water temperature by 6 degrees as compared to an unheated, uncovered pool.

*U.S. GOVERNMENT PRINTING OFFICE: 1977--249-831